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APPLIED MECHANICS REVIEWS

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ELECTROANALOGIC METHODS

II *Solution of continuum-mechanics problem by continuous-type conductive procedures*

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PART I of this article (see AMR, January 1956) comprises an account of electroanalogic solution of problems of electric and magnetic nature (112).[1] This part II encompasses an account of similar solution of continuum-mechanics problem—elastic, thermic, hydrodynamic, and aerodynamic in nature.

9 ELASTICITY

Mindlin and Salvadori (113) and, more generally, Higgins (114) advance detailed account of the mathematical theory of the various analogies between the torsion of cylinders of uniform cross section and current flow in a conducting medium. The latter's paper (114) contained a concise comparative account of the early electroanalogic work done in the 1930's (4, 84, 115–121).

Most of this early work hinges on expression of the torsion problem in terms of the conjugate torsion function, ψ which satisfies the Laplacian equation $\nabla^2\psi = 0$. If, however, it is expressed in terms of the normalized stress function Ψ, which satisfies the Poissonian equation $\nabla^2\Psi = -2$, analogic solution is yet possible—as evidenced in the recent work of Edamoto (122, 123,) with a unique type of low-frequency a-c electrolytic tank; Gilbert (124), using a-c of sufficiently high frequency to produce an appreciable displacement current; and Waner and Soroka (125), by a conducting-paper analog device.

In discussion of this last named work, Rosenthal and his colleagues (126) point out that both obviation of the necessity of introducing current over the surface of the conducting paper and retention of the obvious advantages stemming from use of the paper can be effected by solution in terms of the Laplacian ψ, rather than the Poissonian Ψ; and later exemplify their comment by corresponding solution of a torsion problem (127).

Their initial use (126) of conducting-paper analogs is as a complementary aid in photoelastic investigation—in much the same manner as electrolytic tank analogs had been used earlier (128–130). Thus, photoelastic investigation yields the directions and difference of the principal stresses: but complete solution of a problem also requires knowledge of the sum of these stresses. This sum can be obtained electroanalogically, as is detailed by Theocaris (131) and by Stokey and Hughes (132) in their interesting studies of determination of the isopachic lines in certain problems of plane stress.

Both electrolytic tank and conducting-paper analogs enable solution of problems of pure flexure, or of combined torsion and flexure, of cylinders of singly or multiply connected cross section, as detailed two decades ago by Negoro (119–121), and more recently by Malavard and Boscher (133) and by Friedmann and Rosenthal (134).

Torsion of a cylinder of nonuniform cross section (shafting) comprises a rotationally symmetric problem. Detailed account of the mathematical theory of the various electroanalogies is given by Mindlin and Salvadori (113) and, more generally, by Higgins (135). The latter's paper encompasses concise comparative outline of most of the consequential conducting tank and sheet work (136–144).

Prior to development of electroanalogs in the 1930's, Prandtl's (1902–1903) membrane or soap-film analog of the torsion problem was that most used. Difficulties associated with production and maintenance of the soap film are, in some measure, avoided by use of the little-known electrically conducting liquid-surface analog proposed by Piccard and Baes (145, 146) and subsequently improved by others (147, 148), as detailed in (114). However, this electroanalogic method found very limited use. It is the more conventional conducting tank, plate, and paper analogs which have experienced considerable adoption, development, and improvement over the past 15 years, as evidenced by comparison of somewhat paralleling descriptive accounts by Pérès (148) in 1938 and Malavard (149) in 1953.

In conclusion of this section, especial interest may attend remark of Boiten and Biezeno's (150) comparative study of solution of the torsion problem of a grooved cylinder by soap film and conducting-plate analogs and by the numerical procedure of relaxation—to the end that the former states that "the use of the relaxation method saved at least 50 per cent in time and money. Consequently, for practical applications we have, at Delft, abandoned the experimental methods [for the torsion problem]."

10 THERMAL TRANSMISSION

A well-detailed account of the mathematical theory of various analogies between heat transmission in thermally conducting media and current flow in electrically conducting media is encompassed in Jakob's book (151). Less general, more qualitative

[1] Numbers in parentheses indicate References at end of paper, parts I and II.

accounts have been advanced by Laclemandiere (152), Brokmeier (153), Malavard and Miroux (154), and others (155).

Interestingly, one of the earliest electroanalogic investigations is Volterra's (156) study of temperature distribution in a tunnel in a mountain by use of a conducting plate; and one of the latest is Wiles and Graves' (157) study of temperature distribution associated with a mine tunnel (airway) with a damp floor, by use of the electrolytic tank. A somewhat similar parallelism exists between the early electrolytic tank work of Langmuir, Adams, and Meikle (158) on determination of shape factors pertinent to calculation of the heat flow through furnace walls, and two recent studies by Andrews (159) and by de Haas, Sandiford, and Cameron (160) on determination of shape factors pertinent to calculation of heat flow from buried pipes and buried or ducted electric cables. The latter's paper, as also that by Germain (6) giving account of study of temperature distribution in the partitioning walls of a coke furnace, is of especial interest relative to outline of means of encompassing nonuniform thermal conductivity over the domain of interest.

A connected body of work on closely associated problems is entailed in the investigations of Awberry (161), Schofield (162, 163), and Bruckmayer (164, 165), by use of conducting plates, and the more recent series of papers by Kayan (166–171), utilizing measurement of electrical resistance of a continuous or pierced metal sheet. The essential problem under consideration is that of heat flow and temperature distribution associated with structures such as occur in building practice: walls, floor slabs, or spaces; variously insulated; containing or noncontaining heat sources or sinks of flat, spherical, or cylindrical form.

The thermal studies mentioned to this point are, in the main, of fairly regular geometry and boundary conditions. More generally, however, the flexibility of electroanalogic methods is such as to render them peculiarly fitted to study of thermal effects in irregularly shaped or complexly structured bodies which (possibly) encompass arrays of heat sources. Exemplificative of such use are the recent electrolytic tank studies of Farr and Wilson (3) on transformer cores, Lutz (172) on mercury rectifier tubes, Kettleborough (173) on cooled gas-turbine blades, Baumann (174) on cooled gas-turbine rotor bodies, McNall and Janssen (175) on transistors, and the interesting d-c conducting-paper Lava-slab analog developed by Simmons (176), for study of temperature distribution in devices comprising an array of uniformly generating heat sources such as occur in nuclear piles.

In conclusion, attention may be directed to such associated electroanalogic techniques as Jakob's early suggestion (1913) of the trace of isothermal lines by analogic use of iron filings arrayed by a strong magnetic field (177); Finzi-Contini's (178) and Kayan's (166) suggestions of use of jellied electrolytes; and—an inversion!—Gohar's (179) solution of electric field distribution by heat-conduction analogs.

11 HYDRODYNAMICS

The mathematical theory of the various analogies between hydrodynamic and electric fields is not well integrated in books on hydrodynamics: gaining desired information commonly entails hunt through the various texts by Bassett, Lamb, Milne-Thomson, and others. The writer has found Lamb's account (180) to be well complemented by Lazzarino's (181) detailed paper.

An interesting use of the electrolytic tank is for determination of the essential operating characteristics and optimum design features of hydrodynamically lubricated bearings. This work spans the past quarter century, as first effected in early papers by Kingsbury (182) and Needs (183); further developed by Morgan, Muskat, and Reed (184) to encompass such effects as external sources of lubrication and various types of grooving; and culminated in Kettleborough's (185) recent comparative study of the relative merits of tilting-pad bearings and stepped thrust bearings.

Use of electroanalogic procedures for study of fluid flow through porous media (according to D'Arcy's law) finds important applications in various phases of petroleum technology and hydraulic engineering. The general mathematical theory linking fluid flow through porous media and conductive flow of electric current is excellently set forth in Muskat's (186, 187) two books.

A considerable body of electroanalogic work with application to petroleum technology (as initiated by Muskat and his colleagues, and subsequently developed by them and other workers) is encompassed in the periodical literature. In the large, two major types of electroanalogs are to be discerned: "electrolytic" analogs based on ion migration in electrolyte-soaked blotting paper, and "potentiometric" analogs based on current flow in conducting tanks or sheets. The initiation, development, considerable improvement, and various applications (forced flooding, recycling, in-situ combustion, and other forms of oil and gas recovery) of blotting-paper analogs are to be traced to date in the papers by Muskat and his early colleagues (188–194) and by recent workers (195, 196).

Blotting-paper models give a direct graphic history of fluid particle motion in regular, infinite well-networks. However, potentiometric analogs (metal sheets were later supplanted by electrolytic tanks) are better suited to irregular well-networks. As first employed by Hurst and his colleagues (197–199), they furnished the potential distribution, wherefrom the fluid particle motion along the streamlines was graphically or numerically determined. Subsequently, the initial analogs were improved by Lee (200, 201) through use of a 4-probe arrangement which (in conjunction with pantagraph and automatic recording apparatus) both substantially reduces the time of use and enables simultaneous determination of the streamline paths of the fluid particles and the voltage gradients. The considerable practical value of these analogs is evidenced in the accounts of studies pertinent to producing fields, as obtained by both the earlier (201, 202) and the improved (203) potentiometric models. A good account of the basic analytic theory of potentiometric analogs, together with critical examination of the validity of use of the iso-vol type (204), is encompassed in an excellent paper by Muskat (205).

A closely associated domain of electroanalogic application comprises study of phenomena associated with gravity-flow systems: interference effects among artesian wells (206), groundwater flow into drainage systems (207), and the numerous, long-studied problems connected with large hydraulic structures (208, 209). Of these last, the semielectroanalogic pioneering work of Vreedenburg and Stevens (210) on water seepage through dams has been refined by Muskat (211) and his colleagues (212) into a wholly electroanalogic procedure.

A closely linked problem is that of ascertaining the flow under dams and weirs and the correspondingly exerted uplift pressures thereon (213–217). A series of electrolytic tank studies made in India by Ram, Vaidhianathan, and associates (218–221), yielding analogic data in good agreement with values obtained both from measured values on scaled models (222) and from theoretical equations derived by Weaver (223), firmly establish the values of electroanalogic study of this problem.

General account of electroanalogic study of various hydrodynamic problems in nonporous media are encompassed in papers by Hohenemser (224), Pérès and Malavard (225–227), and Dolcetta (228). Particular problems are entailed in the papers of Larras (229) and Malavard (230) on "clapotis"; of Pérès and Malavard (231) on free streamlines in jet flow; of

Rouse and Hassan (232) on cavitation-free inlets and contractions; and in the account by Borden, Shelton, and Ball (233) of the electrolytic tank constructed at the David W. Taylor Model Basin for the study of flow about two-dimensional bodies and three-dimensional rotational symmetric bodies such as torpedos. Thereto, the interesting work of Hubbard (234) on the free surfaces of various flow systems, especially of rotationally symmetric form, is to be noted. As a final instance, the recent work of Zangar (235) on dam pressures produced by earthquake motion may be remarked.

In virtue of their flexibility, electroanalogic procedures are well suited to investigation of hydrodynamic forms of complicated shape or structure, such as occur in the prime problem of turbomachine theory: determination of the characteristics of flow about the cascade (grid of blades). The early work of Hahn (236, 237) and Gerber (238) on isolated blades is encompassed and extended in the study by de Haller (239, 240) of the velocity and potential distribution over the cross section of the two-dimensionally considered cascade by means of a carefully engineered a-c electrolytic tank and in the work of Malavard and associates (241, 242), Hargest (243, 244), Otsuka (245, 246), Revuz (247), and Diggle and Hartell (20).

12 AERODYNAMICS

The use of electroanalogic methods for study of aerodynamic flow problems has continually accelerated over the past 30 years. This steady expansion can be traced through a long series of papers and reports: from the early work by Relf (248), Ferrari (249), and Hohenemser (224) on use of the electrolytic tank for determining the streamlines about a two-dimensional airfoil in an incompressible, invisid fluid, to the recent general accounts of numerous present-day uses of this and other analogs by Diprose (250) and by Kuchemann and Redshaw (251).

Use of the electrolytic tank for determination of various phenomena (streamline flow, lifting pressure, velocity and acceleration potential, etc.) attending the flow of an incompressible fluid over two and three-dimensional airfoils is encompassed in papers by Pérès and Malavard (252–264), and others (265–272). Among similarly effected flow studies on rotationally symmetric bodies are to be noted those on cowlings (273–275), diffusers (57, 276–278), air intakes (279), and various other devices. Flow over a grid of airfoils is detailed by Malavard and Siestrunck (241, 242) and by Otsuka (245, 246).

Wind-tunnel research is encompassed in the work of Malavard (280) on wall corrections; and of Hubbard (234) and Babister and his associates (281) on contraction shapes.

The effects associated with compressible fluid flow can also be studied in the electrolytic tank, as evidenced in the early work of Taylor and Sharman (282) in the direct plane, and of Busemann (283), Vandrey (284), and Poritsky, Sells, and Danforth (285) in the hodograph plane.

As a final, rather unique application, attention may be directed to Siestrunck's (286) investigation on the propellor.

13 ERRORS IN ELECTROLYTIC-TANK ANALOGS

Various causes of error and remark as to remedy of these errors are discussed in many of the papers mentioned to this point. The collective discussion is so scattered, however, that it is not feasible to attempt summarization here. Rather, attention may be directed to a series of papers especially concerned with investigation and obviation of sources of error: by Softy and Jungerman (287); Sander and Yates (91, 288), particularly concerned with accurate electric field mapping as an auxiliary in electron optics investigation; and Einstein (289), who advances a very detailed investigation of the major errors and specific suggestion for reducing or obviating them.

Particular aspects of error are considered in the papers by Rollet (290) on nonlinear conduction caused by polarization at the electrode surfaces; Shipley and Goodeve (291) on polarization and electrode corrosion effects; Thiele and Himpan (292), Baud and Tank (293), and Schund and Schwenklagen (294) on the choice, nature, and surface treatment of electrode materials; Burfoot (295) and Weston (296) on the optimum size, shape, and carriaging of probes; and of Einstein (297) on an improved bridge assembly for ascertaining null points. Finally, the papers of Bogolyubov and Shamaev (298, 299) and of Schade (300) may be remarked—especially the latter's, which details how accuracy can be improved by graphical correction of inherent errors.

Manual point-by-point field plotting is a tedious, laborious, time-consuming task which also contributes to error. Accordingly, automatic plotting devices, mostly servo-controlled, are now commonly employed for accurate large-scale work. Typical of such are the arrangements described by Lee (200), Green (301), Mickelsen (302), Schmidl (303), and others (39, 91, 92, 94–96, 304). A useful semiautomatic plotter is remarked by Bradshaw in the discussion of (32).

14 ERRORS IN CONDUCTING-PAPER ANALOGS

Paper rendered electrically conductive through admixture of conducting particles (Teledeltos paper) is now much used in analog work (305, 306). An excellent critical study of the sources of error and of merits relative to the electrolytic tank is given by Germain (6). Again, Scott (92) has discussed the sources of error and means of minimizing them.

The use of high-quality ordinary paper, rather than treated high-resistivity paper, for mapping equipotential lines is proposed by Murray and Hollway (307), who put it to good use in designing the poles of a synchrotron magnet. Dahlin (308) has made a careful study of the effects of structure, quality of material, humidity, and other factors affecting the conductivity of such papers.

15 MISCELLANEOUS

Bloch (77) remarks on the correct interpretations of the phenomena reported by Guébhard (309, 310), Voigt (311), and Ditscheiner (312). Schaefer and Stachowiack (313) discuss the distribution of high-frequency currents in human tissues and bone; and its title evidences the theme in Kretzschmer's (314) paper.

16 CLOSURE

A companion paper, on the solution of problems by d-c resistor and a-c impedance network analogs, is now being prepared. For inclusion in an addenda to this second paper, the author would appreciate receiving note of pertinent references not listed in the present paper.

BIBLIOGRAPHY

112 Higgins, T. J., Electroanalogic methods: I Solution of electrical problems by continuous-type conductive procedures, AMR **9**, pp. 1–4, Jan. 1955.

113 Mindlin, R. D., and Salvadori, M. G., "Analogies," chap. 16, Handbook of experimental stress analysis, New York, John Wiley and Sons, 1950.

114 Higgins, T. J., Analogic experimental methods in stress analysis as exemplified by Saint-Venant's torsion problem, *Proc. Soc. exp. Stress Anal.* **2**, 2, 17–27, 1944.

115 Stone, M., The general torsion problem: solution by electric analogy, *Proc. 3rd Int. Congr. appl. Mech.*, Stockholm **2**, 167–170, 1930.

116 Biezeno, C. B., and Koch, J. J., Some examples of electric stress determination (in German), *Ing.-Arch.* **4**, 384–393, 1933.

117 Cranz, H., Experimental solution of the torsion problem (in German), *Ing.-Arch.* **4**, 506–509, 1933.

118 Cranz, H., Analog studies for solution of plane-potential problems (in German), *Ing.-Arch.* **7**, 432–438, 1936.

119 Negoro, S., The use of the electric bath in solving torsion and bending problems, *Trans. Soc. mech. Engrs. Japan* **2**, 112–116, 1936.

120 Negoro, S., Method of solving torsion and bending problems of a bar with axial holes, *Sci. Rep. Res. Inst. Tohôku Univ. Japan (A)* **12**, 517–528, 1938.

121 Negoro, S., On a method of solution of torsion and bending problems of a straight beam with axial holes, *Trans. Soc. mech. Engrs. Japan* **4**, 4, 6–9, 1938.

122 Edamoto, I., An electrical method for solving the torsion problem of a cylindrical body, *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 215–218. AMR **8**, Rev. 2298.

123 Edamoto, I., An electrolyte tank method of solution of the torsion problem of a cylindrical body, *Sci. Rep. Ritu (B)* **35**, 41, 25–28, 1954.

124 Gilbert, E. O., and Gilbert, E. G., A capacitively coupled fluid mapper for 2-dimensional distributed source field problems, *Trans. AIEE* **72**, part 1, 345–351, 1953; *Elect. Engng. Chicago* **72**, 600–605, July 1953.

125 Waner, N. S., and Soroka, W. W., Stress concentrations for structural angles in torsion by the conducting sheet analogy, *Proc. Soc. exp. Stress Anal.* **11**, 1, 19–26, discussion, 27–34, 1953. AMR **7**, Rev. 3502.

126 Rosenthal, D., Mackey, R. C., and Dahl, P. R. (discussion of Ref. 125), *Proc. Soc. exp. Stress Anal.* **11**, 1, 27–30, 1953.

127 Friedmann, N. G., Yamamoto, Y., and Rosenthal, D., Solution of torsional problems with the aid of the conducting sheet analogy, *Univ. Calif. Dept. Engng. tech. Rep.*, Dec. 1953.

128 Meyer, H., and Tank, F., An improved electric procedure for solution of the equation $\nabla^2\phi = 0$ and its application in photoelastic investigation (in German), *Helv. phys. Acta* **8**, 315–317, 1935.

129 Tank, F., Baud, R. V., and Shiltknecht, E., New facilities of the photoelastic laboratory at the Federal Technical High School and at the Federal Material Testing Institute (in German), *Schweiz. Bauztg.* **109**, 20, 249–254, 1937.

130 Malavard, L., Electric analogy as an auxiliary method in photoelasticity (in French), *C. R. Acad. Sci. Paris* **206**, 38–39, Jan. 1938.

131 Theocaris, P. S., The distribution of tension around a rivet hole due to a force applied on the rivet (in French), Univ. Libre Bruxelles. 1951–1952.

132 Stokey, W. F., and Hughes, W. F., Tests of the conducting paper analogy for determining isopachic lines, *Proc. Soc. exp. Stress Anal.* **12**, 2, 77–82, 1954.

133 Malavard, L., and Boscher, J., Electric analogs for studying the flexure of beams (in French), *C. R. Acad. Sci. Paris* **236**, 1130–1133, Mar. 1953.

134 Friedmann, N. G., and Rosenthal, D., Solution of combined bending and torsion problems by means of the electrical conducting sheet analogy, *J. aero. Sci.* **22**, 8, 571–572, Aug. 1955.

135 Higgins, T. J., Stress analysis of shafting exemplified by Saint-Venant's torsion problem, *Proc. Soc. exp. Stress Anal.* **3**, 1, 94–101, 1945.

136 Jacobsen, L. S., Torsional-stress concentrations in shafts of circular cross section and variable diameter, *Trans. ASME* **47**, 619–638, discussion, 639–641, 1925.

137 Jacobsen, L. S., Torsional stresses in shafts having grooves or holes, *J. appl. Mech.* **2**, A154–A155, 1935.

138 Thum, A., and Bautz, W., Determination of stress-concentration in torsed shafts by an electric analogy (in German), *ZVDI* **78**, 17–19, 1934.

139 Thum, A., and Bautz, W., Determination of torsional stress in notched structural members by analog studies (in German), *Arch. tech. Messen* **4**, V 132–11, T 113–115, 1934.

140 Thum, A., and Bautz, W., On the question of shape factor (in German), *ZVDI* **79**, 1303–1306, 1935.

141 Thum, A., and Bautz, W., The shape function: the influence of form on physical properties (in German), *Schweiz. Bauztg.* **106**, 25–30, 1935.

142 Salet, G., Determination of points of stress in torsed shafts by means of an electric analog (in French), *Bull. Assn. tech. marit. aéro.* **40**, 341–350, 1936.

143 Salet, G., Improvement of the method of determination of points of stress in torsed shafts by means of an electric analog (in French), *Bull. Assn. tech. marit. aéro.* **41**, 295–303, 1937.

144 Walther, A., An electric approximation equation for rotationally symmetric potential flow (in German), *Z. tech. Phys.* **16**, 19–22, 1935.

145 Piccard, A., and Baes, L., New experimental procedure relative to the application of surfaces of constant curvature for the solution of the problem of torsion of prismatic bars (in French), *Proc. 2nd int. Congr. appl. Mech.*, Zurich, 1926, pp. 195–199.

146 Piccard, A., and Johner, W., An indirect experimental method for the determination of torsional stresses in prismatic bars (in German), Festschrift Prof. Dr. A. Stodla zum 70 Geburtstag, Zurich and Leipzig, Orell Fussle Verlag, 1929, pp. 489–498.

147 Sunatani, C., Matuyma, T., and Hatamura, M., The solution of torsion problems by means of a liquid surface, *Trans. Soc. mech. Engrs. Japan* **2**, 423–427, 1936; *Tohôku Univ. tech. Rep.* **12**, 374–396, 1938.

148 Pérès, J., Analogic methods in applied mechanics (in French), *Proc. 5th int. Congr. appl. Mech.*, Cambridge, Mass., 1938, pp. 9–19.

149 Malavard, L., Electric analogies in elasticity (in French), *Laboratories*, no. 8, pp. 19–21, 23, 25, 27, 29, Dec. 1953.

150 Boiten, R. G., and Biezeno, C. B., The strength and stiffness of a circular section, loaded in torsion and weakened by a deep keyway (in Dutch), *Ingenieur*, p. 0.1, 1945. Abstracted in the discussion of Ref. 125.

151 Jakob, M., Heat transfer, New York, John Wiley and Sons, 1949, 758 pp. See Sec. 20–3: Liquid or solid electrical conductor as model for steady-state problem. AMR **3**, Rev. 785.

152 Laclemandiere, L. de, Experimental study of the transmission of heat in the transient state by aid of electric and thermal analogies (in French), Communication to Asso. Ing. Chauffage et de Ventilation de France et aux Eleves du Cours Sup. de Chauffage Ind. de l'Office de Repartition du Charbon, July 8 and Oct. 31, 1946.

153 Brokmeier, K. H., Possibilities of analog study in heat transfer research (in German), *VDE-Fachberichte* **15**, 1951.

154 Malavard, L., and Miroux, J., Electrical analogies for heat transfer problems, *Engng. Digest* **13**, 416–420, Dec. 1952. A summary of original paper in *Proc. 4th int. Congr. Industrial Heating*, Paris, 1952, group 1, sec. 13, Pap. no. 82, 7 pp.

155 Boelter, L. M. K., Cherry, V. H., and Johnson, H. A., Heat transfer, Berkeley, Los Angeles, Univ. Calif. Press, 1942.

156 Volterra, V., On the temperature in the interior of a mountain (in Italian), *Nuovo Cim.* **4**, series 6, 111–126, 1912.

157 Wiles, G. G., and Grave, D. F. H., Heat flow studies using an electrolytic tank, *J. Chem. Met. Mining Soc. South Africa* **55**, 6, 149–153, Dec. 1954.

158 Langmuir, I., Adams, E. Q., and Meikle, Flow of heat through furnace walls: the shape factor, *Trans. Amer. Electrochem. Soc.* **24**, 53–76, discussion 76–84, 1913.

159 Andrews, R. V., Solving conductive heat transfer problems with electrical-analogue shape factors, *Chem. Engng. Prog.* **51**, 2, 67F–71F, Feb. 1955.

160 de Haas, E., Sandiford, P. J., and Cameron, A. W. W., An analog solution of cable heat flow problems, *Trans. AIEE*, part II, Power apparatus and systems, no. 18, 315–318, discussion, 318–322, June 1955.

161 Awberry, J. H., and Schofield, F. H., Effect of shape on heat-loss through insulation, *5th int. Congr. Refrig. Rome* **3**, 591–610, 1928.

162 Schofield, F. H., The heat-loss from a cylinder embedded in an insulating wall, *Phil. Mag.* **12**, 7, 329–349, 1931.

163 Schofield, F. H., The heat-loss from a plate embedded in an insulating wall, *Phil. Mag.* **12**, 7, 480–500, 1930.

164 Bruckmayer, F., Electric analog studies for the solution of technical problems in heat (in German), *Archiv. Wärmewirtschaft Dampfkesselwesen* **20**, 23–25, 1939.

165 Bruckmayer, F., Electric analog measuring means for thermal short-circuits in cold storage structures (in German), *ZVDI* **88**, 270–272, 1944.

166 Kayan, C. F., An electrical geometrical analogue for complex heat flow, *Trans. ASME* **67**, 713–718, Nov. 1945.

167 Kayan, C. F., Heat flow and temperature analysis of complex structures through application of electrical resistance concept, *6th int. Congr. appl. Mech.*, Paris, Sept. 1946.

168 Kayan, C. F., Temperature patterns and heat transfer for a wall containing a submerged metal member, *Refrig. Engng.* **51**, 533–537, 568, 574, 582, 1946.

169 Kayan, C. F., Effect of floor slab on building structure temperature and heat flow, *Trans. Amer. Soc. Heat. Vent. Eng.* **53**, 377–396, 1947; *Heating, Piping, & Air Conditioning* **19**, 6, 103–111, June 1947. AMR **1**, Rev. 387.

170 Kayan, C. F., Temperatures and heat flow for a concrete slab with imbedded pipes, *Refrig. Engng.* **45**, 2, 143–151, Aug. 1947. AMR **1**, Rev. 197.

171 Kayan, C. F., Electric analogue studies on panels with embedded tubes, *Heating, Piping, & Air Conditioning* **22**, 5, 123–130, 1950.

172 Lutz, M. A., Study of cathode phenomena in mercury arcs (in French), *Rev. Gen. Elect.* **59**, 153–169, 1950.

173 Kettleborough, C. F., An analogue study of the temperature distribution in cooled gas-turbine blades, *Brit. J. appl. Phys.* **6**, 5, 174–176, May 1955. AMR **8**, Rev. 2898.

174 Baumann, H., Determination of temperature distribution in

gas-turbine rotor bodies and cylinders by the electrolytic tank method, *Brown Boveri Rev.* **40,** 5/6, 189–196, Apr. 1954. Abridged in *Engng. Digest* **15,** 4, 139–141, Apr. 1954.

175 McNall, P. E., Jr., and Janssen, J. E., An electrolytic analog applied to the solution of a thermal conduction problem, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-45. AMR **8,** Rev. 2519.

176 Simmons, W. R., An electrical geometrical analogue for two-directional steady-state heat conduction with uniform internal heat generation, ASME Semi-Ann. Meet., Pittsburgh, Pa., June 1954. Pap. 54—SA-49, 13 pp. AMR **8,** Rev. 802.

177 Jakob, M., American heat transfer measurements by the two-plate method (in German), *Z. Kalte-Indus.* **29,** 83–87, 1922.

178 Finzi-Contini, B., An electric analogy (in Italian), *Il Politecnico, Milan* **85,** 291–298, 1937.

179 Gohar, M. K., Experimental determinations of the electric field and equipotential surfaces using the heat conduction analogy, *J. appl. Phys.* **25,** 6, 805–807, June 1954.

180 Lamb, H., Hydrodynamics, 6th ed., Cambridge, England, University Press, 1932; New York, Dover Publications, Inc., 1945, pp. 65 and 210.

181 Lazzarino, O., The analogy between hydrodynamic and electromagnetic fields, *Atti. Accad. Gioenia Sci. Nat. Catania, Mem.* **12,** 1–16, 1923.

182 Kingsbury, A., On problems in the theory of fluid-film lubrication, with an experimental method of solution, *Trans. ASME* **53,** no. APM-53-5, 59–75, 1931.

183 Needs, S. J., Effects of side leakage in 120-degree centrally supported journal bearings, *Trans. ASME* **56,** 721–732, 1934.

184 Morgan, F., Muskat, M., and Reed, D. W., Studies in lubrication. VI. Electrolytic models of full journal bearings, *J. appl. Phys.* **11,** 141–152, 1940.

185 Kettleborough, C. F., An electrolytic-tank investigation into stepped thrust-bearings, *Chartered mech. Engr.* **2,** 3, 145, Mar. 1955; *Trans. Inst. mech. Engrs.*, advance paper, pub. pending.

186 Muskat, M., The flow of homogeneous fluids through porous media, New York, McGraw-Hill Book Co., Inc., 1937; reissue, Ann Arbor, Edwards Bros., 1946. See: Sec. 9.17. The progress of water-oil interface-electrolytic-model experiments, pp. 561–617; also pp. 234–244.

187 Muskat, M., Physical principles of oil production, New York, McGraw-Hill Book Co., Inc., 1949, 922 pp. See: Sec. 11.8. The electrical analyzer; Sec. 12.1. The shapes of injection-fluid fronts in well networks as determined by electrolytic-model experiments; Sec. 13.6. The theory of potentiometric models; Sec. 13.7. An illustrative application of the potentiometric model to cycling systems.

188 Muskat, M., Potential distribution in large cylindrical disks with partially penetrating electrodes, *Physics* **2,** 329–364, 1932.

189 Wyckoff, R. D., Botset, H. G., and Muskat, M., The mechanics of porous flow applied to water-flooding problems, *Trans. Amer. Inst. min. metall. Engrs., Petr. Div.* **103,** 219–240, discussion 240–249, 1933.

190 Muskat, M., and Wyckoff, R. D., A theoretical analysis of water-flooding networks, *Amer. Inst. min. metall. Engrs., Petr. Engng., Tech. Pub.* no. 507, 1–29, 1933; summarized in *Trans. Amer. Inst. min. metall. Engrs., Petr. Div.* **107,** 62–76, 1934.

191 Muskat, M., Two fluid systems in porous media. The encroachment of water into an oil sand, *Physics* **5,** 250–264, 1934.

192 Wyckoff, R. D., and Botset, H. G., An experimental study of the motion of particles in systems of complex potential distribution, *Physics* **5,** 265–275, 1934.

193 Botset, H. G., The electrolytic model and its application to the study of recovery problems, *Trans. Amer. Inst. min. metall. Engrs., Petr. Div.* **165,** 15–25, 1946.

194 Swearingen, J. S., Predicting wet-gas recovery in recycling operations, *Oil Weekly* **96,** pp. 30, 32–35, 36, 38, Dec. 25, 1939.

195 Aronofsky, J. S., Mobility ratio—its influence on flood patterns during water encroachment, *Trans. Amer. Inst. min. metall. Engrs.* **195,** p. 15, 1952.

196 Ramey, H. J., Jr., and Nabor, G. W., A blotter-type electrolytic model determination of areal sweeps in oil recovery by in-situ combustion, *Trans. Amer. Inst. min. metall. Engrs., Petr. Div.* **201,** 35–39, 1954; *J. Petr. Technol.* **6,** 5, 35–39, May 1954. AMR **8,** Rev. 850.

197 Hurst, W., Electrical models as an aid in visualizing flow in condensate reservoirs, *The Petr. Eng.*, 1941.

198 Hurst, W., and McCarty, G. M., The application of electrical models to the study of re-cycling operations in gas distillate fields, *Amer. Petr. Inst. Drill. and Prod. Practice*, pp. 228–240, 1941.

199 Hurst, W., and van Everdingen, A. F., Performance of distillate reservoirs in gas cycling, *Petr. Technol.* **9,** Tech. pap. 1969, 1–15, Jan. 1946; *Trans. Amer. Inst. min. metall. Engrs.* **165,** 36–51, 1946.

200 Lee, B. D., Potentiometric-model studies of fluid flow in petroleum reservoirs, *Petr. Technol.* **10,** Tech. pap. 2262, 1–26, Sept. 1947; *Trans. Inst. min. metall. Engrs.* **174,** 41–66, 1948. See also: Wolf, A., *Oil and Gas J.* **46,** 95–98, Apr. 15, 1948.

201 Horner, W. L., and Bruce, W. A., Electrical-model studies of secondary recovery, Supplement to Secondary recovery of oil in the United States, 1942, *Proc. Amer. Petr. Inst.* **24,** 4, 190–198, 1943.

202 Kelton, F. C., An electrolytic model study of cycling in the Grapeland field, Texas, Supplement to Secondary recovery of oil in the United States, *Proc. Amer. Petr. Inst.* **24,** 4, 199–205, 1943.

203 Marshall, D. L., and Olivery, L. R., Some uses and limitations of model studies in cycling, *Petr. Technol.* **10,** Tech. pap. 2230, 1–21, 1947; *Trans. Amer. Inst. min. metall. Engrs.* **174,** 67–87, 1948.

204 Miller, M. G., and Lents, M. R., Performance of Bodcaw reservoir, Cotton Valley field cycling project; new methods of predicting gas condensate reservoir performance compared to field data. Paper presented at Spring Meeting, Mid-Continent Division, Amer. Petr. Inst. Div. of Prod., Oklahoma City, June 1946; *Oil and Gas J.* **46,** 111–112, 119, Mar. 18, 1948.

205 Muskat, M., The theory of potentiometric models, *Petr. Technol.* **11,** 1, 1–6, Nov. 1948; *Trans. Amer. Inst. min. metall. Engrs., Petr. Div.* **179,** 216–221, 1949.

206 Babbett, H. E., and Caldwell, D. H., The free surface around, and the interference between, gravity wells, *Engng. Exp. Sta. Univ. Ill., Bull. Ser.* no. 374, Jan. 7, 1948.

207 Childs, E. C., The water table, equipotentials and streamlines in drained land, *Soil Science* **56,** 317–330, 1943.

208 Puppini, U., Electric analogs for the study of the motion of seeping water (in Italian), *Mem. Reale Accad. Sci. Bologna, Cl. Sci. Fis.* **9,** 7, 79–84, 1921–1922; *Monitore Tecnico* **28,** 209–214, 1922.

209 Pavlovsky, N. N., Motion of water under dams, Proc. Congr. Int. Grand Barrages, Stockholm **4,** 179–192. See also: Pavlovsky, N. N., Theory of ground water flow under hydroengineering structures and its principal applications (in Russian), Leningrad, State Publishing House, 1922, 750 pp., especially pp. 524–560.

210 Vreedenburg, C. G., and Stevens, O., Electric investigation of potential flows in fluids, especially applied to two-dimensional groundwater flows (in Dutch), *Ingenieur* **48,** p. 187, 1933.

211 Muskat, M., The seepage of water through dams with vertical faces, *Physics* **6,** 402–415, 1935.

212 Wyckoff, R. D., and Reed, D. W., Electrical conduction models for the solution of water seepage problems, *Physics* **6,** 395–401, 1935.

213 Lane, E. W., *U. S. Dept. Int. Bur. Reclamation, Tech. mem.* nos. 384 and 388, 1934.

214 Lane, E. W., Campbell, F. B., and Price, W. H., The flow net and the electric analogy, *Civil Engng.* **4,** 510–514, 1934.

215 Harza, L. F., Uplift and seepage under dams on sand, *Trans. ASCE* **100,** 1352–1385, discussion pp. 1386–1406, 1935.

216 Casagrande, A., Seepage through dams, *J. New England Water Works Assoc.* **51,** 6, 131–172, June 1937.

217 Retlov, B. F., Electrical analogy applied to three-dimensional study of percolation under dams built on pervious heterogeneous foundations, *Trans. 2nd Congr. Large Dams*, Washington, D. C. **5,** 73–85, 1936.

218 Ram, G., Vaidhianathan, V. I., Taylor, E. M., Potential distribution in infinite conductors and uplift under dams and weirs, *Proc. Indian Acad. Sci.* **2,** 26–29, 1935.

219 Vaidhianathan, V. I., Ram, G., and Taylor, E. M., Uplift pressure on weirs: single sheet of piling, *Proc. Indian Acad. Sci.* **2,** 646–655, 1935.

220 Vaidhianathan, V. I., and Ram, G., Electrical method of investigating uplift pressures on dams, *Res. Pub. Punjab Irrigation Res. Inst.* **5,** p. 4, 1935.

221 Ram, G., and Vaidhianathan, V. I., Uplift pressure and design of weirs with two sheet piles, *Proc. Indian Acad. Sci.* **4,** 147–156 1936.

222 Taylor, E. M., and Uppal, H. L., *Res. Pub. Punjab Irrigation Res. Inst.* **2,** p. 6, Feb. 1934.

223 Weaver, W., Uplift pressures on dams, *J. Math. Phys.* **11,** 2, 114–145, 1932.

224 Hohenemser, K., Experimental solution of plane potential problems (in German), *Forsch. Geb. Ing.-Wes.* **2,** 370–371, 1931.

225 Malavard, L., Application of electric analogies to the solution of some problems in hydrodynamics (in French), *Pub. sci. tech. Min. Air. France* no. 57, 1932.

226 Pérès, J., and Malavard, L., On electric analogies in hydrodynamics (in French), *C. R. Acad. Sci. Paris* **134,** 1314–1316, Apr. 18, 1932.

227 Pérès, J., and Malavard, L., Application of the electric tank to some questions in the mechanics of fluids (in French), *Asso. tech. Marit. Aero.*, June 1938.

228 Dolcetta, A., Apparatus for the experimental solution of hydrodynamic problems by the method of electrical analogy (in Italian), *Energia elett.* **26**, p. 461, 1949.

229 Larras, J., Means of solution of the problem of rippling by an electro-analogic method (in French), *Ann. Ponts Chauss.* **13**, 207–225, 1936.

230 Malavard, L., Experimental realization of the electric analogy of M. J. Larras for the analytic problem of rippling (in French), *Ann. Ponts Chauss.* **14**, 226–231, 1936.

231 Pérès, J., and Malavard, L., Analogic realizations of jet flow (in French), *C. R. Acad. Sci. Paris* **206**, 418–420, Feb. 7, 1938.

232 Rouse, H., and Hassan, M. M., Cavitation free inlets and contractions, *Mech. Engng.* **71**, 213–216, 1949. AMR **2**, Rev. 1156.

233 Borden, A., Shelton, G. L., and Ball, W. E., Jr., An electrolytic tank developed for obtaining velocity and pressure distributions about hydrodynamic forms, *David W. Taylor Mod. Basin Rep.* no. 824, 35 pp., Apr. 1953. AMR **6**, Rev. 3873.

234 Hubbard, P. G., Application of the electrical analogy in fluid mechanics research, *Rev. sci. Instrum.* **20**, 11, 802–807, Nov. 1949. AMR **4**, Rev. 400.

235 Zangar, C. N., Hydrodynamic pressures on dams due to horizontal earthquakes, *Proc. Soc. exp. Stress Anal.* **10**, 2, 93–102, 1953. AMR **7**, Rev. 482.

236 Hahn, E., Experimental method for solution of the equations of fluid motion (in French), *Proc. 2nd int. Congr. appl. Mech.*, Zurich, pp. 532–535, 1928; *Rev. gen. Élec.* **21**, 485–489, Mar. 1927.

237 Hahn, E. P., Experimental solution of hydrodynamic equations, *Engineering* **123**, 178–180, 1927.

238 Gerber, H., and Ackert, J., Experimental methods for determination of potential-flow maps (in German), *Escher Wyss Mitt.* no. 6, 171–176, 1928.

239 de Haller, P., Applications of electrical analogy to the investigation of cascades, *Sulzer tech. Rev.* no. 3/4, 11–17, 1947.

240 de Haller, P., Applications of electric analogy for the study of grills of blades (cascade) (in French), *Bull. tech. Suisse Rom.* **73**, p. 25, 1947.

241 Malavard, L., and Siestrunck, R., A method for study of nonlimited lattices of (airfoils) of arbitrary cross section (in French), Comm. Congr. Nat. Aviation Française, 1945.

242 Malavard, L., Germain, P., and Siestrunck, R., Calculation of the distribution of velocity over the cross sections of grills of blades (cascades) (in French), *Rech. aéro.* no. 4, July 1948. AMR **2**, Rev. 254.

243 Hargest, T. J., An electric tank for the determination of theoretical velocity distributions, *Aero. Res. Counc. Lond. Rep. Mem.* 2699, 9 pp., Apr. 1949, publ. 1952. AMR **6**, Rev. 1040.

244 Hargest, T. J., The theoretical pressure distribution around some conventional turbine blades in cascade, *Aero. Res. Counc. Lond. Rep. Mem.* 2765, 10 pp., Mar. 1950, publ. 1953.

245 Otsuka, S., The influence of the size of electrodes in connection with latticed wing solution with the aid of electricity (in Japanese, English abstract), *Rep. Inst. Sci. Technol. Tokyo* **4**, 5/6, 150, 154, 1950. AMR **5**, Rev. 588.

246 Otsuka, S., Latticed wing solution with the aid of electricity, *Proc. 2nd Japan nat. Congr. appl. Mech.*, pp. 207–211, 1952. AMR **5**, Rev. 587.

247 Revuz, J., Families of profiles of blades for axial compressors (in French), *Rech. aéro.* no. 37, 11–16, 1954.

248 Relf, E. F., An electrical method for tracing streamlines about bodies in a perfect fluid, *Aero. Res. Counc. Lond. Rep. Mem.* 905, 1924.

249 Ferrari, S., Experimental determination of aerodynamic fields in two and three dimensions by means of their analogies with electric fields (in Italian), *Aerotecnica* **17**, p. 453, 1930.

250 Diprose, K. V., Analogue computing in aeronautics, *J. roy. aero. Soc.* **59**, 535, 479–493, 1955. AMR **9**, Rev. 227.

251 Kuchemann, D., and Redshaw, S. C., Some problems in aerodynamics and their solution by electrical analogy, *Roy. Aircraft Establ. tech. Note Aero.* 2323, Aug. 1954.

252 Pérès, J., and Malavard, L., Application of the electric method to a problem concerning airfoils of finite aspect ratio (in French), *C. R. Acad. Sci. Paris* **195**, 599–601, Oct. 1932.

253 Malavard, L., On the fundamental problem concerning airfoils of finite aspect ratio (in French), *C. R. Acad. Sci. Paris* **195**, 733–736, Nov. 1932.

254 Pérès, J., and Malavard, L., Application of the electric method to some questions concerning wing lift (in French), *Sci. Aérienne* **6**, p. 360, Nov./Dec. 1936.

255 Pérès, J., The method of electric analogies in aerodynamics (in French), *Sci. Aérienne* **5**, 1–00, 1936.

256 Malavard, L., Application of electric analogies to some problems in aerodynamics (in French), *Rev. tech. Asso. Ing. Aéro.*, 3 parts, 1938.

257 Malavard, L., Study of some technical problems relative to wing theory (in French), *Publ. sci. tech. Min. Air. France* no. **153**, 1939.

258 Malavard, L., Rheoelectric solution of problems of conformal mapping and application to the theory of airfoils (in French), *C. R. Acad. Sci. Paris* **218**, 106–108, Jan. 1944.

259 Malavard, L., Aerodynamic application of experimental analogic computation (in French), Comm. Congr. Nat. Aviation Française, Apr. 1945.

260 Pérès, J., Malavard, L., and Romani, L., A nonlinear problem of wing theory. Applications to determination of maximum lift (in French), *Rapport tech. G.R.A.* no. 20, 1946.

261 Legras, J., and Malavard, L., Electric tank study of problems of the lifting surface (in French), *Proc. 6th int. Congr. appl. Mech., Paris*, Sept. 1946.

262 Malavard, L., The use of rheoelectric analogies in certain aerodynamical problems, *J. roy. aero. Soc.* **51**, 441, 739–753, discussion, 753–756, Sept. 1947.

263 Malavard, L., Some recent applications of electroanalogic methods (in French), *Proc. Colloq. Methodes de Calcul*, pp. 55–71, 1949.

264 Malavard, L., and Duquenne, R., Study of lifting surfaces by rheoelectric analogs (in French), *Rech. aéro.* no. **23**, 3–12, 1951. AMR **5**, Rev. 1528.

265 Schmidt, K., Experimental solution of two-dimensional potential problems by electric dipole fields (in German), *Ing.-Arch.* **14**, 30–52, 1943.

266 Jones, W. P., Note on lifting plane theory with special reference to Falkner's approximate method and a proposed electrical device for measuring downwash distributions, *Aero. Res. Counc. Lond. Rep. Mem.* 2225, May 1946, pp. 1–3. AMR **2**, Rev. 1413.

267 Germain, P., Application of the rheoelectric method for calculating flow over conical bodies of small angle (in French), *C. R. Acad. Sci. Paris* **226**, 1126–1127, Apr. 1948.

268 Campbell, W. F., Two electrical analogies for the pressure distribution on a lifting surface, *Nat. Res. Counc. Canada mech. Engng. rep.* no. MA-219, 45 pp., Oct. 1949. AMR **4**, Rev. 287.

269 Stenstrom, L., The SAAB gradient tank, an aid to aeroplane design, *SAAB Sonics* no. 12, p. 18, 1950.

270 Landahl, M. T., and Stark, V. J. E., An electrical analogy for solving the oscillating-surface problem for incompressible nonviscid flow, *Roy. Inst. Technol. Div. Aero., Stockholm, KTH-Aero TN* 34, 19 pp., 1953. AMR **7**, Rev. 1162.

271 Matsunaga, S., A proposal on the electric tank method for study of a symmetrical aerofoil with a rear suction slot and a retractable flap, *J. roy. aero. Soc.* **58**, 434–435, 1954.

272 Falkner, V. M., and Gandy, R. W., Notes on the use of an electric tank for the solution of wing loading problems, *Aero. Res. Counc. Lond.* 10,022, Oct. 1946.

273 Lewis, W. T. O., Flow over cowlings, *Aero. Res. Counc. Lond.* no. 8375, 1945.

274 Lewis, W. T. O., Potential flow apparatus, *Aeronautics*, Dec. 1946.

275 Lewis, W. T. O., and Newman, E. J., Investigations into the flow over cowlings for radial aero engines using potential flow apparatus, *Bristol Aeroplane Co. Rep.* no. KR 66/44, July 1944.

276 Lewis, W. T. O., and Newman, G. J. E., The development of a diffuser outline having specific velocity distribution characteristics by means of the potential flow apparatus, *Bristol Aeroplane Co. Rep.* no. KR 76/45, 1945.

277 Cheers, F., Raymer, W. G., and Fowler, R. G., Preliminary tests on electric potential flow apparatus, *Aero. Res. Counc. Lond. Rep. Mem.* 2205, 1945.

278 Cheers, F., and Raymer, W. G., Tests in the NPL electric tank on a 4:1 axisymmetrical diffuser having a discontinuity in the wall velocity, *Aero. Res. Counc. Lond. Rep. Mem.* 9505, Mar. 1946.

279 Hahnemann, H., and Bammert, K., Tests in an electrolytic tank on a ramming and non-ramming air intake for a gas turbine power plant, *M. of S. Volkenrode Mon.* **11**, p. 2; R and T. 182, 1946.

280 Malavard, L., Electroanalogic method for the calculation of wall corrections (in French), *C. R. Acad. Sci. Paris* **204**, 1052–1054, Apr. 1937.

281 Babister, A., Marshall, W., Lilley, C. M., Sills, E. C., and Deards, S. R., The use of a potential flow tank for testing axisymmetric contraction shapes suitable for wind tunnels, *Coll. Aero. Cranfield Rep.* **46**, 15 pp., 17 figs., Apr. 1951. AMR **4**, Rev. 4505.

282 Taylor, G. I., and Sharman, C. F., A mechanical method for solving problems of flow in compressible fluids, *Aero. Res. Counc. Lond. Rep. Mem.* 1195, 1928; *Proc. roy. Soc. Lond* (*A*) **121**, 194–217, 1928.

283 Busemann, A., The hodograph method for gas dynamics (in German), *ZAMM* **17**, 73–79, 1937.

284 Vandrey, F., Investigations concerning the treatment of

plane subsonic flow with the aid of electric analogy (in German), Dissertation Gottingen, 1944. Trans. ms. of S. R. and T. no. 807.

285 Poritsky, H., Sells, B. E., and Danforth, C. E., Graphical, mechanical and electrical means for the determination of compressible flows, *J. appl. Mech.* **17**, 1, 37–46, Mar. 1950. AMR 4, Rev. 1289.

286 Siestrunck, R., On a method of rheoelectric solution of the problems of propeller vortices (in French), *C. R. Acad. Sci. Paris* **219**, 411–413, 1944.

287 Softy, S., and Jungerman, J., Electrolytic tank measurements in three dimensions, *Rev. sci. Instrum.* **23**, 306–307, 1952.

288 Sander, K. F., and Yates, J. G., The accurate mapping of electric fields in an electrolytic tank, *Proc. Inst. elect. Eng.* **100**, 74, part II, 167–175, discussion, 176–183, Apr. 1953.

289 Einstein, P. A., Factors limiting the accuracy of the electrolytic plotting tanks, *Brit. J. appl. Phys.* **2**, 49–55, 1951.

290 Rollet, A. P., The behavior of different metals in the electrolysis of water by alternating current (in French), *C. R. Acad. Sci. Paris* **185**, 457–460, 1927.

291 Shipley, J. W., and Goodeve, C. F., The law of alternating current electrolysis and the electrolytic capacity of metallic electrodes, *Trans. Amer. Electrochem. Soc.* **52**, 375–402, 1927.

292 Thiele, R., and Himpan, J., The choice of electrode materials for field mapping in electric tanks (in German), *Die Telefunkenrohre* **18**, 50–00, 1940.

293 Baud, R. V., and Tank, F., Determination of two dimensional potential fields with arbitrary boundary conditions (in German), *Schweiz. Bauztg.* **111**, 176–177, 1938.

294 Schund, H., and Schwenklagen, H., New electrode materials for field measurements (in German), *Die Telefunkenrohre* **20**, 47–48, 1942.

295 Burfoot, J. C., Probe impedance in the electrolytic tank, *Brit. J. appl. Phys.* **6**, 2, 67–68, Feb. 1955.

296 Weston, M. K., An improved probe assembly for use with an electrolytic tank, *J. sci. Instrum.* **32**, p. 367, 1955.

297 Einstein, P. A., Improved balance indication for bridge with Wagner earthing arms, using a cathode-ray oscillograph, *J. sci. Instrum.* **27**, p. 27, 1950.

298 Bogolyubov, V. E., and Shamaev, Y. M., Electrolytic tank having semi-conducting walls, *Dokladi Akad. Nauk SSSR* **98**, 3, 423–426, Sept. 1954.

299 Bogolyubov, V. E., and Shamaev, Y. M., Electrolytic tank with walls causing minimum distortion (in Russian), *Elektrichestvo* no. 10, 68–72, 1954.

300 Schade, G., The d-c field in electrolytic tanks: graphical construction of the field (in German), *Dtsch. Elektrotech.* no. 12, 444–446, 1954.

301 Green, P. E., Automatic plotting of electrostatic fields, *Rev. sci. Instrum.* **19**, 646–653, 1948.

302 Mickelsen, J. K., Automatic equipment and techniques for field mapping, *Gen. Elect. Rev.* **52**, 19–23, Nov. 1949.

303 Schmidl, H., Electrolytic tank with automatic plotting of potential lines (in German), *Electrotech. u. Maschinenb.* **69**, 7, 155–161, July 1952.

304 Gelfand, R., Shinn, B. J., and Tuteur, F. B., An automatic field plotter, *Trans. AIEE*, part I, Communications and Electronics, no. 17, 73–78, Mar. 1955.

305 Hotchkiss, G., Electrosensitive recording paper for facsimile telegraph apparatus and graphic chart instruments, *Western Union tech. Rev.* **2**, 4, p. 176, Oct. 1948.

306 Helm, S., and Hand, A. R., Field plotting method uses models, *Indust. Lab.* **4**, 9, 122–124, Sept. 1953.

307 Murray, C. T., and Hollway, D. L., Equipotential plotting, using untreated writing paper, *J. appl. Phys.* **24**, p. 110, 1953.

308 Dahlin, E. B., Equipotential plotting table, *Rev. sci. Instrum.* 24, 951–953, Oct. 1954.

309 Guébhard, A., Electrochemical demarkation of the equipotential lines on any part of the plane (in French), *J. Phys. Rad.* **1**, 2, 205–222, 1882.

310 Guébhard, A., On electrochemical demarkation of systems of equipotential lines (in French), *J. Phys. Rad.* **1**, 2, 483–492, 1882.

311 Voigt, W., *Mitt. aus dem math.-phys. Lab. Konigsberg* no. 7, 1881.

312 Ditscheiner, Concerning Guébhard's rings (in French), *J. Phys.* **2**, 87–89, 1883. See comment by Guébhard, 328–335.

313 Schaefer, H., and Stachowiack, R., Probe measurements on models for determination of the field distribution in multilayered dielectrics produced by uhf-capacitor coupling (in German), *Z. tech. Phys.* **21**, 367–372, 1940.

314 Kretzschmer, F., Flow form and Reynolds number of measuring orifice (in German), *Forschungsheft* **381**, 1–28, 1936; abstracted in *Forsch. Geb. Ing.-Wes.* **7**, p. 312, 1936.

Books Received for Review

BAINER, R., KEPNER, R. A., AND BARGER, E. L., Principles of farm machinery (Ferguson Foundation Agricultural Engineering Series), New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, xi + 571 pp. $8.75.

BEGGS, J., Mechanism (McGraw-Hill Series in Mechanical Engineering), New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, xiii + 418 pp. $6.50.

BOBEK, K., HEIB, A., AND SCHMIDT, F., Stahlleichtbau von Maschinen (Konstruktions-bücher 1), 2nd ed., rev. and enlarged, Berlin, Gottingen, Heidelberg, Springer-Verlag, 1955, vii + 183 pp. DM 24.

DENBIGH, K., The principles of chemical equilibrium, Cambridge, The University Press, 1955, xxi + 491 pp. $7.50.

FAMOUS PROBLEMS AND OTHER MONOGRAPHS (including: Klein, F., Famous problems of elementary geometry, 92 pp.; Sheppard, W. F., From determinant to tensor, 127 pp.; Macmahon, P. A., Introduction to combinatory analysis, viii + 71 pp.; Mordell, L. J., Three lectures on Fermat's last theorem, 31 pp.), New York, Chelsea Publishing Company, 1955. $3.25.

LEE, J. F., AND SEARS, F., Thermodynamics (Addison-Wesley Series in Mechanical Engineering), Cambridge 42, Mass., Addison-Wesley Publishing Company, Inc., 1955, xiii + 543 pp. $8.50.

PFLEIDERER, C., Die Kreiselpumpen für Flüssigkeiten und Gase, Wasserpumpen, Ventilatoren, Turbogebläse, Turbokompressoren, 4th ed., rev. and enlarged, Berlin, Gottingen, Heidelberg, Springer-Verlag, 1955, xi + 589 pp. DM 58.50.

RAŠKOVIĆ, D., Otpornost Mater'iala, Belgrade, Universiteti Beogradi, 1955, x + 300 pp. (paperbound).

SIEBEL, E., AND LUDWIG, N., editors, Die Prüfung der metallischen Werkstoffe (Handbuch der Werkstoffprüfung, Band II), 2nd ed., Berlin, Gottingen, Heidelberg, Springer-Verlag, 1955, xv + 754 pp. DM 118.50.

TOWN, H. C., Hydraulic and pneumatic operation of machines, New York, Philosophical Library, 1956, 192 pp. $7.50.

U. S. DEPT. OF COMMERCE, NATL. BUREAU OF STANDARDS, circular 553 (hardback), The ICSS-NBS method of designating colors and a dictionary of color names, Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C., v + 158 pp. $2.00.

YARWOOD, J., High vacuum technique, theory, practice, industrial applications and properties of materials, 3rd ed., rev., New York, John Wiley & Sons, Inc., 1955, viii + 208 pp. $5.50

Theoretical and Experimental Methods

(See also Revs. 373, 375, 387, 395, 411, 418, 425, 428, 459, 464, 496, 512, 524, 525, 528, 553, 556, 558, 563, 571, 575, 607)

352. Coddington, E. A., and Levinson, N., Theory of ordinary differential equations, New York, McGraw-Hill Book Co., Inc., 1955, xii + 429 pp. $8.50.

Reviewer does not know any textbook on the subject in question comparable with this brilliant and broad foundation of the theory of ordinary differential equations. A perfectly rigorous and most modern viewpoint of presentation, an abundance of original ideas, large sections with new results which enrich the vast field of differential equations, perfect paper and excellent print, all will bring real intellectual enjoyment to every mathematician studying the book. Engineers and physicists will, perhaps, find it somewhat difficult to become familiar with the comparatively

complicated notation and compact diction applied in this branch of mathematics, but the results of a conscientious study will reward them richly for their efforts.

Book presupposes a mature knowledge of linear algebra (especially of matrixes), of the essentials of functions of a complex variable, and also a certain familiarity with the theory of Lebesgue integrals. The text is concerned primarily with theoretical regards and emphasizes general ideas and methods rather than special results.

Book opens with a brief preface on its aim and on the general approach taken. Then come the detailed contents of material treated; after that the text, references (general as well as separately for each chapter), and the volume ends with a detailed subject index. Content is divided into 17 chapters with 98 subtopics. Each chapter ends with instructive problems for solving. There are altogether 172 such problems in the book and they give, in many cases, additional material which is not considered in the text.

Chap. 1 is devoted to the existence and uniqueness of solutions (Cauchy-Peano fundamental theorem and the method of successive approximations) both for a single equation of the first order and for systems of such equations. Considered are both the real and complex domains.

Chap. 2 goes far beyond ordinary treatments on the subject. It presents the fundamental Carathéodory existence theorem for solutions in the extended sense and introduces the important notions of the maximum and minimum solutions. It also gives a more profound insight into the problem of uniqueness and its connection with successive approximations as well as with a continuous dependence of solutions on the initial conditions and parameters.

Following main part has for subject the detailed theory of linear homogeneous and nonhomogeneous systems. Careful attention is paid to equations with constant, periodic, and analytic coefficients. Chapter concludes with beautiful considerations on asymptotic properties of solutions of linear systems.

Chaps. 4 and 5 bring an excellent presentation of the analytic theory of linear systems with isolated singularities of the first and second kind. The Frobenius method of solving the nth-order equations by means of infinite series is of special significance for technical applications (complicated mathematical problems in construction of dams, plates on elastic foundation, etc.). Of course, mathematician's attention must be called first of all to a new treatment of systems with regular singular points and to a quite original application of the Phragmén-Lindelöf theorem to the study of the irregular singular points.

Following sections on asymptotic behavior of solutions of linear systems with a large parameter contain new facts taken, doubtless, from original research work. The results are of considerable importance in mathematical physics; for example, in the boundary-layer theory.

Reviewer knows of no better theory of eigenvalue problems than that presented in chaps. 7–12. Considered are self-adjoint problems on finite intervals, singular self-adjoint boundary-value problems for second and nth-order equations, and also nonself-adjoint problems. Material abounds in results from original work of the authors which cannot be found anywhere else in published form. Fundamental significance of boundary value and expansion problems in all branches of applied mathematics and mathematical physics is generally known.

The stability theory (asymptotic, orbital, conditional stability) and behavior of solutions of the stable manifolds form the subject of chap. 13 and also contain original material. These topics are considered in much more detailed manner than is customary.

Following two main parts constitute an excellent and, in many respects, new presentation of the perturbation theory for autonomous and nonautonomous systems having periodic solutions and for two-dimensional autonomous systems. The subject is of greatest importance for the vast field of nonlinear mechanics.

Chap. 16 presents the Poincaré-Bendixson theory of two-dimensional autonomous systems, and the text ends with a fine study of differential equations on a torus.

This excellent authoritative work needs no recommendation. Reviewer takes this opportunity of commending the publishers and the consulting editor of International Series in Pure and Applied Mathematics for enriching in such an excellent manner the field of mathematical literature.

V. Vodička, Czechoslovakia

353. Starkey, B. J., Laplace transforms for electrical engineers, London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1955, 279 pp. $10.

Author briefly reviews nonclassical methods of solving linear ordinary differential equations with constant coefficients: complex vector representation of steady-state sinusoidal variations in linear electrical networks, Fourier series for periodic and Fourier integrals for nonperiodic time functions, and "cisoidal" functions for damped sinusoids. Fourier series and integral equations are incorrectly stated by omission of factors of π and 2π. Discussion contains fundamental errors leading to internally inconsistent equations. Real and complex quantities are freely equated.

Author introduces Laplace transformation and its basic properties and discusses applications to electric and electronic circuits. Complex variables, integration in the complex plane, and residue theorem are discussed without reference to concept of analytic functions. Cauchy-Riemann equations are introduced much later in appendix. Complex variable theory is used to evaluate several inverse Laplace transformations. Appendix contains brief discussion of Bessel, Legendre, Laguerre, and other functions, and a fairly extensive table of Laplace transforms.

Author makes great effort to present material in physically meaningful terms but, in so doing, takes liberties with mathematical principles, which reviewer feels is unwarranted. Other authors have presented same subject matter in more understandable fashion without the least sacrifice of mathematical rigor.

A. W. Gessner, Germany

354. Acrivos, A., and Amundson, N. R., Applications of matrix mathematics to chemical engineering problems, *Indust. Engng. Chem.* **47,** 8, 1533–1541, Aug. 1955.

Authors have attempted to indicate the advantages which are available to engineers by the use of matrix theory. After a brief discussion of various theoretical considerations, a number of examples in the fields of equilibrium and transient staged operations have been worked out in detail, i.e., multicomponent distillation and stirred reactors.

Considering the limitations of space imposed by a single journal article, reviewer feels that authors have accomplished their desired purpose. This paper should stimulate future thinking by many chemical engineers.

L. Lapidus, USA

355. Kogbetliantz, E. G., Solution of linear equations by diagonalization of coefficients matrix, *Quart. appl. Math.* **13,** 2, 123–132, July 1955.

Author gives at great length but without detailed proofs a method for solving a system of linear equations with any complex coefficients without first replacing these complex equations by real ones, which leads to an undesirable doubling of the unknowns. To accomplish this, the coefficient matrixes of the system of equations are diagonalized by successive approximation and at

the same time the proper unitary matrixes of transformation are calculated. The solution of the equations is thus reduced to a pure multiplication of matrixes. The errors of the method do not accumulate, the convergence is relatively slow, but sufficient when electronic computing machines are used. Author says that, for the diagonalization of a 32×32 matrix in the discussed way with the aid of IBM 701 type machine, 23 minutes were needed.

Besides the general case, the important special forms of coefficient matrixes are also discussed in detail.

F. Engelmann, Germany

356. **Kron, G., Tearing and interconnecting as a form of transformation,** *Quart. appl. Math.* **13,** 2, 147–159, July 1955.

Paper outlines author's previously published methods of solving complex physical systems by tearing apart, solving the pieces, and recombining the solutions by tensor transformations. Main emphasis is on transformation concept and invariance of power in terms of electrical networks. Importance of orthogonality is stressed because forces must sometimes be introduced at cuts. Author mentions rotating machines, elastic structures, difference of tearing from partitioning methods. B. Hoffman, USA

357. **Rosser, J. B., Explicit remainder terms for some asymptotic series,** *J. rational Mech. Analysis* **4,** 4, 595–626, July 1955.

Author studies asymptotic series and remainder for ${}_A\int^B h(x)H^M(x)dx$, M large. Results are applied to incomplete gamma function. Paper gives improved techniques for computing higher terms of series. Error bounds are derived.

Y. Luke, USA

358. **Daly, B. B., Transparent charts for solving engineering problems, direct results from characteristic curves,** *Engineering* 179, 4664, 762–765, June 1955.

359. **Gurk, H. M., The use of stability charts in the synthesis of numerical quadrature formulae,** *Quart. appl. Math.* **13,** 1, 73–78, Apr. 1955.

Quadrature formulas are classified according to their stability chart characteristics. Methods for synthesizing formulas are described. Emphasis is on methods applicable for real time simulation problems. Y. Luke, USA

360. **Tick, L. J., Gaussian outputs from non-Gaussian inputs,** *J. aero. Sci.* **22,** 3, p. 208, Mar. 1955.

Mr. Tick's note is a fairly strong criticism of a paper by Mazelsky [AMR **7**, Rev. 3467] which appeared in a prior issue of the same journal. Tick's principal objection is to a theorem which Mazelsky purports to prove (and which has been generally accepted for some time, at least in most engineering circles) to the effect that if a linear system is excited by *any* stationary random process whose frequency spectrum is wide and flat compared with the frequency response of the system, then the response of the system tends to be a Gaussian process. Tick's criticism is based on the justifiable observation that relative "*wide-bandedness*" implies "*uncorrelatedness*" over times somewhat shorter than the significant weighting time of the system, but that this does *not necessarily* mean *independence*, as is required for the application of the central limit theorem to this problem. This reviewer feels that the theorem is correct for all cases of random excitation which occur in real life (i.e., excluding mathematical contrivances) since, in these cases, the eventual decay of the autocorrelation function with increasing intervals of time is, in fact, due to and evidence of an increasing degree of independence. This fact is ordinarily verified by the investigator or designer, not simply by observation of a spectral curve, but through his knowledge of the general physical nature of the origin of the excitation.

There seems to be a growing need for a generally accepted word for such processes. Goldman, in his book, "Information theory" [Prentice-Hall, 1953], uses "ergodic sequence" in this sense; the great majority of mathematicians working in the field of "stochastic processes" seem to confine themselves to sequences of this type, and most engineers refer to "noiselike" in this sense. Thus, if Mazelsky had prefaced his remarks with the statement that he was considering only such processes, most of the criticism would then be unfounded and the theorem would stand correct and continue to be useful. R. M. Stewart, USA

361. **Lighthill, M. J., and Whitham, G. B., On kinematic waves, II. A theory of traffic flow on long crowded roads,** *Proc. roy. Soc. Lond.* (*A*) **229,** 317–345, 1955.

The unidirectional flow of traffic on a crowded divided highway is treated as a problem in kinematics of continua. A functional relationship is stipulated between the flow q (number of vehicles passing a stationary observer per unit of time) and the concentration k (number of vehicles per unit of length of the highway). The "conservation of vehicles" is then expressed by a quasilinear partial differential equation of the first order for the concentration. For a homogeneous stretch of road, the characteristics in the t, x-plane are straight lines of the slope dq/dk and concentration and flow are constant along any characteristic. A given "state" (k, q) propagates with the (group) velocity dq/dk, whereas a given vehicle advances with the (phase) velocity q/k, which, for the assumed relation between k and q, exceeds the group velocity. In regions of the t, x-plane where characteristics intersect, discontinuities of flow and concentration must be considered. If the jumps in these quantities across a discontinuity are denoted by Δq and Δk, the discontinuity is found to propagate with the speed $\Delta q/\Delta k$. The consideration of nonhomogeneous road conditions leads to a theory of bottlenecks. Queuing at a traffic light is treated as an example. Various secondary effects are briefly discussed. W. Prager, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 411, 444, 447, 587)

362. **Polaczek, K., An introduction to mechanisms [Getriebelehre: eine Einführung],** München, Carl Hanser Verlag, 1955, 56 pp. DM 4.80.

Author defines the components of a mechanism as rigid bodies which are connected like links in a chain and have definite relative motion with respect to one fixed member. The mechanism becomes a "Getriebe" (driven mechanism) if one link is set in motion. (In English texts, however, the term "mechanism" *alone* requires the inclusion of a driven member in the system.) Reviewer believes that the definition should not be limited to rigid bodies, because links having deformation under imparted motion (i.e., gases and liquids) are also possible. Author then describes the motion of rotation about fixed centers and instantaneous centers, supplementing the discussion with clear sketches. The problem of finding the velocity of single points graphically is considered in the next chapter in which link-to-link and velocity-component methods are explained. These principles are then applied to three examples: a slider-crank mechanism and two four-link chains. Determination of the acceleration of points in linear, circular, and curvilinear motion is handled clearly. Swinging-arm mechanisms and cams with flat-face and roll followers are then described.

Fifteen illustrative problems and a brief chapter on the forces

in mechanisms are also included. Although this booklet is small in volume, it gives an excellently illustrated and comprehensive treatment of the subject. C. B. Ludwig, USA

363. Götzlinger, J., and Johnsson, S., Dynamic forces in cranes, *Acta Polyt.* **175** (*Mechanical Engineering Series* **3**, no. 7), 34 pp., 1955.

A comparison is made between the U. S., the German, and the Swedish standards for calculation of dynamic forces in cranes.

Formulas for the maximum *hoisting factor* are deduced and checked by experiment. By the aid of statistical measurements on cranes in service a reduction factor, which takes into account the actual load conditons, is arrived at.

Thereafter an expression is given for the *traveling* factor arising when one of the crane's wheels passes a real joint. The results from measurements on an overhead traveling crane show considerable scatter but confirm the theory fairly well.

Finally, an attempt is made to show the improbability of the hoisting and traveling factors occurring simultaneously and what further reductions can be made on account of this.

From authors' summary

364. Raher, W., Theory of impact between rigid bodies (in German), *Öst. Ing.-Arch.* **9**, 1, 55–68, 1955.

Impact problems of classical mechanics, involving both rigid and deformable bodies, can be treated analytically by the use of a motor symbolism, as described in earlier literature. Author points out that the symbolism, which is based on d'Alembert's principle, provides a concise form of notation, and sometimes permits the formulation of motion equations that are more tractable than those provided by more conventional approaches. Several examples are developed in detail to illustrate the advantages of the motor symbolism. J. S. Arnold, USA

365. Gale, E. I., Accessory linkages which have certain stabilizing properties, *Amer. math. Monthly* **62**, 94–99, 1955.

Two different linkage mechanisms may describe identical curves. However, each may have a position of instability (a dead center) at which there is an ambiguity of possible subsequent motion. If these two dead centers occur at different parts of the curve, the two mechanisms can be combined into one without a position of instability. As examples of the foregoing, the Hart cell and the Peaucellier cell are both inversors. When used in describing an elliptic cissoid, only one half of a Hart cell need be added to a Peaucellier cell to eliminate the instability. Other examples given are combinations of inversors to describe hyperbolas, lemniscates, and limaçons.

Other methods which have been used to eliminate dead centers are duplicate mechanisms which are placed out-of-phase and parts of toothed gear wheels. M. Goldberg, USA

366. Weirich, H., Determination of the pole of inertia and the inertia pole curve (in German), *Öst. Ing.-Arch.* **9**, 2/3, 230–238, 1955.

A purely graphical method is given for locating the instantaneous pole of inertia and thus the polar locus of a rigid body in plane motion. This extends the work of Federhofer [AMR **4**, Rev. 4375]. C. M. Ablow, USA

367. Fiala, E., Lateral forces on rolling pneumatic tires (in German), *ZVDI* **96**, 29, 973–979, Oct. 1954.

The available experimental results on the behavior of pneumatic tires of vehicles can be represented by theoretically proved formulas. The theoretical idea is based on simplified models for the stress distribution in the area of contact between the tire and the ground. From this, some relations are derived for the deformation of the tire and the resulting lateral forces caused by oblique running, inclination of the wheel, and running on a curved path. J. Rotta, Germany

368. Mewes, E., Representation of systems of spatial forces by orthogonally crossing forces (in German), *Ing.-Arch* **22**, 5, 348–356, 1954.

Author recalls that, from a static point of view, three-dimensional forces cannot be reduced to one single force, but either to two forces or to one force and one torque.

He deals in his paper with a spatial way of representation, consisting in replacing spatial forces by two forces, one of them lying in a definite plane and the other one being at right angles to this plane. This representation is called orthogonally crossing forces. Aim of author is to show the advantages given by this system of representation for the determination of forces arising in fastening elements of bodies charged by spatial forces.

Some examples are treated and the relations between orthogonally crossing forces and other ways of representation (three force components and three torque components, or force and torque of the central axis) are given.

D. DeMeulemeester, Belgium

Servomechanisms, Governors, Gyroscopics

(See also Revs. 482, 516, 524, 600, 609)

369. Lawrence, M. J., Automatic control of aircraft center of gravity, *Aero. Engng. Rev.* **14**, 10, 61–65, Oct. 1955.

A description of various systems for maintaining aircraft balance by means of fuel management and a design that allows for the use of the same tank units in both gaging and balancing.

From author's summary

370. Morris, J., Gouriet, G. G., and Head, J. W., Servomechanism performance. Determination of the best values of the parameters when rotating a large mass through a given angular distance, *Aircr. Engng.* **27**, 317, 220–222, July 1955.

The problem of rotating a single large mass through a given angular distance so that the performance shall meet given specifications is considered. Initially it is assumed that the general nature of the torque which can be applied is prescribed, but that certain parameters are at our disposal; the practical determination of the best values of the parameters is considered. For the analogous electrical problem, this is equivalent to determining the best values of certain resistances, capacitances, and inductances in a given network containing variable elements. But in order to solve the problem it is more effective to make alterations and additions to the network, so that it becomes equivalent to one having the required performance; and the way in which this can be achieved for the single rotating mass is discussed.

The restriction to a single-mass system is merely for convenience and simplicity; the procedure discussed is perfectly general.

From authors' summary

371. Van Santen, G. W., Automatic temperature control in a milk pasteurizing plant with the aid of electronic equipment (in Dutch), *Ingenieur* **67**, 14, 0.51–0.56, Apr. 1955.

372. Balise, P. L., Effects of system components in process control, *Trend Engng. Univ. Wash.* **7**, 2, 10–14, Apr. 1955.

Paper describes a simple demonstration process being built at the University of Washington which is intended to illustrate how process parameters may be varied to alter the dynamic response

of a controlled system. Liquid level is the controlled process variable. Author develops equations for single and double capacity processes. These equations have appeared many times in the literature (e.g., "Principles of industrial process control," D. P. Eckman, Wiley and Sons). No bibliography is given.
S. Z. Dushkes, USA

373. **Arthurs, E., and Martin, L. H., Closed expansion of the convolution integral (a generalization of servomechanism error coefficients),** *J. appl. Phys.* **26,** 58–60, 1955.

The integral $r(t) = \int_{-\infty} f(x)w(t-x)dx$ with $w(t)$ as the response function of a servomechanism and with $f(x)$ as forcing function is expanded by decomposition of $f(x)$. This function is split into a continuous part $f_c(x)$ and into a linear combination of unit step functions. It is assumed that the linear combination has a finite number of terms. The integral over f_c undergoes an integration by parts and leads to a convolution integral for the derivative of f_c, if this derivative exists. From here on the procedure is iterated, and a finite number of iterations leads to what is claimed as a closed expansion of the original convolution integral. The method is illustrated by an example for a tracking system. Such terms as "the derivative of the continuous portion of $f(x)$" indicate that a rigorous foundation of the method is still desirable.
H. Bückner, USA

374. **Lee, S.-Y., and Shearer, J. L., Development of a miniature electrohydraulic actuator,** ASME Ann. Meet., N. Y., Nov. 28-Dec. 3, 1954. Pap. 54—A-196, 24 pp.

Vibrations, Balancing

(See also Revs. 389, 551, 586, 591, 592, 611, 620)

375. **Lundquist, S., Subharmonic oscillations in a nonlinear system with positive damping,** *Quart. appl. Math.* **13,** 3, 305–310, Oct., 1955.

376. **Arnold, R. N., Bycroft, G. N., and Warburton, G. B., Forced vibrations of a body on an infinite elastic solid,** *J. appl. Mech.* **22,** 3, 391–400, Sept. 1955.

Authors analyze forced vibrations of a rigid disk resting on a semi-infinite, lossless, elastic medium; four types of forced motion are studied: vertical and horizontal translations, and rotations about vertical and horizontal axes. Approximate solutions of equations of motion of elastic medium are obtained by assuming a stress distribution similar to distribution produced by appropriate static load. Case of disk resting on stratum of finite depth is also analyzed, but quantitative results are evaluated only for rotation about vertical axis. Experiments were performed on all four types of motion for the semi-infinite medium and the stratum, the elastic medium being foam rubber excited by electromagnetic vibrator. Agreement with theoretical results is good. This investigation sheds light on problems of vibrations of machine foundations. Paper exemplifies the combination of advanced mathematical analysis with good experimental techniques as applied to a problem of practical interest. Reviewer deplores that this type of well-balanced paper, which is characteristic of much British work, is increasingly rare in our journals.
M. C. Junger, USA

377. **Edelman, S., Jones, E., and Smith, E. R., Some developments in vibration meaurement,** *J. acoust. Soc. Amer.* **27,** 4, 728–734, July 1955.

Paper describes cemented barium titanate accelerometers of two simple types, an electromagnetic shaker with a symmetrically mounted shake table, a set of barium titanate shakers, and two optical methods of accelerometer calibration, one using a microscope with a stroboscope of wide frequency range and one using a Fizeau type interferometer. Calibration results from 50 to 11,000 cps are given.
From authors' summary

378. **Rubbo, V., Influence of centrifugal force on the frequency of vibration of blades** (in Italian), *Termotecnica* **9,** 7, 295–298, July 1955.

Natural frequencies of turbomachinery blades are increased by the centrifugal force. Author computes this correction factor for the blades of a steam turbine and of an axial compressor by various methods: Stodola's method, which gives values which are too low, and Scharffenberg's and Naef's methods, which are more accurate because they take into account the modification of the shape of the deflected blade by the distributed radial centrifugal load.
M. C. Junger, USA

379. **Yntema, R. T., Simplified procedures and charts for the rapid estimation of bending frequencies of rotating beams,** *NACA TN* 3459, 90 pp., June 1955.

A simplified, but reasonably accurate, method for the calculation of bending frequencies of rotating beams vibrating freely is presented. Utilizing the modes of vibration of nonrotating beams, obtained by the Rayleigh method, the following cases are treated: uniform beans, beams with linearly varying distribution of mass and stiffness, and uniform beams with a mass at the tip. Both the cantilever and the hinged types of beams are considered.

Elaborate graphs and tables are presented to facilitate the evaluation of bending frequencies for various beams and conditions.
W. Ornstein, USA

380. **Lyon, R. H., Response of an elastic plate to localized driving forces,** *J. acoust. Soc. Amer.* **27,** 2, 259–265, Mar. 1955.

The vibration of an infinite elastic plate when driven by a localized driving force is studied theoretically. The dilation and shear potentials are expressed as Fourier integrals, the boundary conditions are applied, and the integrals evaluated by the calculus of residues. It is found that the motion of the plate may be represented by a discrete sum of nonorthogonal eigenmodes. These modes represent two types of waves: propagated and attenuated. The former are obtained from previous work on coincidence transmission. The latter are calculated by a graphical method, and presented in such a manner that they tie in continuously with the propagated modes. Certain unresolved features of the problem are discussed. One previous application of the theoretical results is disclosed.
From author's summary by W. S. Hemp, England

381. **Sobolev, V. A., Dynamic stability of the deformation of a thin bar under eccentric compression and pure bending** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **19,** 65–72, 1954.

A thin bar of rectangular cross section is subjected to bending in its plane by moments or eccentric longitudinal forces applied on the ends, which are hinged for the deformations out of the plane of the bar. The end forces or moments are assumed to consist of a constant part plus a variable, changing with time in accordance with the cosine law. The ensuing oscillatory bending may become unstable.

The partial differential equation of motion, after some simplifications, is reduced to an ordinary second-order equation in time of Hill's type, which is then investigated for the region of instability, whose limits are expressed in terms of physical and elastic constants of the beam and of the applied loads. Experimental study of the problem corroborates the theoretical limiting curves

of the region of instability within 20% and results in some further observations regarding the behavior of the bar.

A. Hrennikoff, Canada

382. Kroll, W., Behavior of small solid particles in vertical vibrating containers (in German), *Forsch. Geb. Ing.-Wes.* **20,** 1, 2–15, 1954.

Subject is of importance in vibrational transport and sieving of particles. Measurements were made of distances between a vibrating surface and the bottom of a layer of particles projected from it, using photographic and stroboscopic methods. Air pressures at the vibrating surface were obtained from the deflection of a diaphragm device. Glass spheres and sand were subjected to 23–100 cps with amplitudes up to 3.7 mm.

Results did not conform to mechanics of particles in vacuum. Consideration of air pressure below the particle layer and of incompressible flow through the layer explained the results for relatively thin layers. For deeper layers, an analysis of gas pressure distribution within the layer and the effect of this distribution on the packing of the particles was used to explain the difference between the simpler theory and experiment.

This appears to be basic work in a little explored field. Some further refinement of the treatment seems desirable.

P. M. Lang, USA

383. Hvingiya, M. V., Small characteristic oscillations of conical spring with constant pitch (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **16,** 73–80, 1953.

The projection of a conical spring with constant pitch is a spiral of Archimedes which simplifies many computations. The spring is loaded with a constant force P. The oscillations are assumed to be small; that is, the neighboring turns of the spring do not touch each other when the vibrating spring is compressed. Small oscillations of such a spring are controlled by the partial differential equation of a beam with variable rigidity. The author solves this differential equation in the usual way by separation of variables and easily obtains the general solution in terms of Bessel functions, but determination of the four constants of integration and the constant of separation (this last constant represents the frequency of vibrations) was quite difficult. These constants were, of course, found from boundary conditions. Conditions on the boundaries $x = 0$, $x = H$ lead to transcendental characteristic equations. The author gives several tables of roots of these equations claiming that the error is much less than 5 per cent. The formula for the frequency is then as accurate as the characteristic number which it contains.

The author compares his exact formula with approximate formulas found by other investigators and shows that the approximate formulas give considerable errors for outside loads which are small as compared with the spring's own weight.

T. Leser, USA

384. Nazarov, A. G., On the dissipation of energy in elastic vibrations (in Russian, with Armenian summary), *Dokladi Akad. Nauk Armyan SSR.* **16,** 77–86, 1953.

Let the restoring force of a vibrating system with one degree of freedom be $Ky(t)$, where $y(t)$ is the displacement at time t. If $R(t)$ is the force due to internal friction, the author writes $R(t) = K[y(t + \tau) - y(t)]$, where it is assumed that $R(t)$ is sufficiently small compared with $Ky(t)$. Concerning τ two hypotheses are made: (1) that τ is constant; (2) that τ is inversely proportional to the frequency. The application of (1) leads to results violently in disagreement with observation, whereas the application of (2) shows good agreement. The idea is then developed in relation to a monochromatic elastic system by introducing two time intervals τ and τ_1, corresponding to normal and tangential stress, obeying (2), and leading to linear equations.

L. M. Milne-Thomson, England

385. Nazarov, A. G., A method of computing the dissipation of energy in elastic vibrations (in Russian, with Armenian summary), *Dokladi Akad. Nauk Armyan SSR.* **16,** 137–140, 1953.

Author shows how energy methods combined with calculations for the undamped systems and experimental observations on the actual system can be used to set up sufficient equations to find approximately the law of dissipation.

L. M. Milne-Thomson, England

386. Takizawa, E., On the equation of longitudinal vibration of a cylinder with moderate thickness, *Mem. Fac. Engng. Univ. Nagoya* **4,** 1, 51–56, July 1952.

An alternate method is presented for obtaining the velocity of propagation of a longitudinal wave in a bar of infinite length. In common with the procedure of Pochhammer and Chree [see: Love's "Theory of elasticity," section 201], author starts with the exact equations of motion. However, by expanding the displacement components in powers of the radius, an iterative procedure is developed for the solution. The velocity of propagation is obtained with an additional correction term to Love's second approximation derived from the Pochhammer-Chree theory. No numerical results are presented by which the magnitude of the refinement can be determined. It would be expected in a paper of this type to find a few references to the published literature.

H. Lurie, USA

Wave Motion in Solids, Impact

(See also Revs. 364, 386, 420, 452, 543, 591, 592)

387. Graham, R. D., An empirical study of planetary waves by means of harmonic analysis, *J. Meteor.* **12,** 4, 298–307, Aug. 1955.

The first twelve harmonics of the observed flow pattern of the upper-level westerlies for the 31 days of January 1952 have been computed and are presented in tabular form. It is shown that the sum of the first three harmonics approximates the hemispheric basic flow in which the moving perturbations are embedded. The observed basic and perturbation flow patterns for January 1952 are shown. The study shows that the representation of a complex flow pattern by a few of its harmonic components preserves its essential features and will simplify the study of possible relationships between this flow pattern and other phenomena such as local weather and solar or geomagnetic effects.

From author's summary

388. Tu, L. Y., Brennan, J. N., and Sauer, J. A., Dispersion of ultrasonic pulse velocity in cylindrical rods, *J. acoust. Soc. Amer.* **27,** 3, 550–555, May 1955.

Authors have investigated experimentally the velocities associated with the dispersion of longitudinal and shear waves in an elastic rod. Transmission and echo techniques, employing quartz or barium titanate transducers, were used to measure travel times of very short pulses in an elastic rod. Data were obtained for several materials. Good agreement with the basic mode of transmission of the exact theory (Pochhammer-Chree) was found for group velocites V_g, associated with longitudinal pulses, when the rod radius to wave-length ratio a/L was less than 0.8. For large values of a/L the group velocity approached the dilatational wave velocity $[(\lambda + 2\mu)/\rho]^{1/2}$. In the vicinity of $a/L = 1$, the Rayleigh surface wave velocity was detected.

Authors use plane wave case of three-dimensional equations of motion as an explanation of their findings for a/L large. They, and the reader, will be interested to know that these findings for a/L large are in agreement with the upper mode of wave transmission of the Mindlin-Herrmann approximate rod theory. (The group velocity-wave-length curves for this theory were given in the reviewer's work in the Proceedings of second U. S. National Congress of Applied Mechanics, p. 179, 1955.)

Authors have presented some interesting and provocative experimental work. J. Miklowitz, USA

389. Davidson, J. F., Impact buckling of deep beams in pure bending, *Quart. J. Mech. appl. Math.* **8,** part I, 81–87, Mar. 1955.

The equations describing lateral instability of a deep beam, first given by Prandtl and Michell, are extended to the dynamic case in which a beam is suddenly loaded by couples acting in the plane of greatest stiffness. These couples are greater than the first critical moment, and, owing to the slight initial curvature of the beam, their application causes it to deflect exponentially with time until the bending couples are released. For a given value of the bending moment, the period of application is determined by the criterion that the amplitude of the subsequent oscillations shall not be excessive. It is found, in most cases, that the resulting impact time is related to the longer of the two gravest component periods of the unloaded beam (torsion and flexure). If the couples are very large, and the gravest component periods widely different, the impact time is fixed by the shorter of the component periods.

From author's summary by W. J. Carter, USA

390. Glauz, R. D., and Lee, E. H., Transient wave analysis in a linear time-dependent material, *J. appl. Phys.* **25,** 8, 947–953, Aug. 1954.

Paper discusses the propagation of one-dimensional extensional waves in a linear solid which shows an elastic, viscous, and a retarded elastic response to stress. Such a solid can be represented by a model consisting of a Kelvin-Voigt element (spring and dashpot in parallel) in series with a Maxwell element (spring and dashpot in series); four parameters are necessary to describe the behavior of the system. The paper may be regarded as a continuation of a previous paper by Lee and Tranter [AMR **7,** Rev. 724], relating to a linear Maxwell solid.

Here the authors discuss the dynamics of a slender rod, with its axis in the direction Ox, extending from $x = 0$ to $x = \infty$; at time $t = 0$, the end $x = 0$ is set in motion with uniform velocity U_0. Since it was found that transform methods were unsuitable, the method of characteristics was used and numerical solutions for the time and space variation of stress, strain, and particle velocity were obtained. Compared with the linear Maxwell solid, the (*stress, time*) curves are almost identical initially, since the viscous portion of the retarded elastic element has not permitted appreciable motion. As time increases, the retarded elastic element flows, relieving some of the stress of the purely elastic element and giving rise to a reversal of the curvature of the (*stress, strain*) curves. For very large values of time, the effect of the retarded elastic element is reduced.

The results can be extended to solve the problem of a rod of finite length, using a method of superposition. It is also possible to derive the solution for the case when a constant stress is applied at the end $x = 0$. R. M. Davies, Wales

391. Nomura, Y., and Takaku, K., On the propagation of elastic waves in an isotropic homogeneous sphere, *J. phys. Soc. Japan* **7,** 204–211, 1952.

A steady-state solution for the case when $\omega_r = \omega_\theta = 0$ and all functions depend on γ and θ only is used to express the dilation and the third component of rotation in terms of constant coefficients of reflection. Both primary P and S diverging waves are considered. It is assumed they are reflected at the surface of the sphere ($r = a$) and also at an infinitesimal rigid sphere at the center of the elastic sphere. Then, the expressions for multiply reflected P and S waves are built up. These expressions are transformed by the method of van der Pol and Bremmer [*Phil. Mag.* (7) **24,** 141–176, 825–864, 1937]. *PP, PS, SP, SS*-waves as well as surface waves are derived.

W. S. Jardetzky, USA

Elasticity Theory

(See also Revs. 384, 413, 416, 419, 421, 429, 433, 435, 436, 450, 505, 602)

392. Langer, B. F., Working-stress criteria for nuclear power plants, *Trans. ASME* **77,** 5, 661–665, July 1955.

See AMR **8,** Rev. 600.

393. Voce, E., Empirical formulae for the determination of stress curves, *J. roy. aero. Soc.* **59,** 533, 362–364, May 1955.

394. Parkus, H., Stress in a centrally heated disk, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 307–311.

Temperature and stress distribution in an infinite, thin disk heated by a temporary heat source which acts from $t = 0$ to $t = \theta$ are investigated. Dynamical effects are considered and residual stresses due to partly plastic flow in the disk are calculated. From author's summary by M. Kuipers, Holland

395. Eringen, A. C., The solution of a class of mixed-mixed boundary value problems in plane elasticity, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 257–265.

With the use of some linear operators, a class of mixed type plane problems of elasticity for an orthotropic rectangular region is solved. The boundary conditions consist of specifying normal and tangential components of displacement vector at two parallel boundaries, and normal stress and tangential displacement components at two other boundaries as arbitrary functions of the tangential coordinates. Thus the solution is a function of eight arbitrary boundary functions which may be chosen to suit the particular purpose.

From author's summary by R. E. Heninger, USA

396. Strub, R. A., Generalized method for the calculation of mechanical and thermal stresses in disks of arbitrary profiles (in French), *Bull. tech. Suisse Rom.* **80,** 8, 97–106, Apr. 1954.

The differential equation of radial displacement in rotating conical disks subject to centrifugal and thermal stresses is integrated graphically by a method suggested by Meissner. Influence coefficients for stresses are given in separate graphs for both convergent and divergent cones subject to radial force at the inside of a conical disk, a tangential force at the same inside surface, a centrifugal force, and a temperature dependent linearly on the radius. Arbitrary profiles are subdivided in conical elements and the stress distribution is analyzed by using the foregoing graphs of influence coefficients and the principle of superposition. By assuming a different value of the modulus of elasticity and of the linear coefficient of thermal expansion for each elementary cone, temperature-dependent properties are taken into consideration. The analysis is restricted to the elastic range. G. A. Zizicas, USA

397. Craven, A. H., Torsion of cylinders with inclusions, *Mathematika* **1,** 96–103, 1954.

This paper deals with the problem of Saint Venant torsion for cross sections with solid or hollow inclusions, the elastic properties of which differ from those of the surrounding material. The method used is an extension of the complex-variable treatment employed by A. C. Stevenson [*Phil. Mag.* (7) **39,** 297–303, 1948; see AMR 2, Rev. 712] in conjunction with homogeneous hollow cross sections. Let C_i with radius $r_i (i = 1, 2, 3; r_1 < r_2 < r_3)$ be concentric circles about the origin of the ζ-plane; let Γ_i be the image in the z-plane of C_i with respect to a mapping $z = f(\zeta)$ which admits a Laurent expansion about $\zeta = 0$. Series solutions are obtained for the case in which the two annuli bounded by Γ_1, Γ_2 and Γ_2, Γ_3 are occupied by different elastic materials (hollow inclusion) and for the case in which the region interior to Γ_1 and the annulus bounded by Γ_1, Γ_2 are occupied by different materials (solid inclusion). The mapping $f(\zeta) = c(1 + \lambda\zeta^n)$, for suitable choices of c, λ, n, yields a nearly circular outer annulus and an inner annulus whose inner boundary is approximately polygonal; it also yields approximately polygonal sections with nearly circular annular inclusions. The torsional rigidities are given in detail for several specific examples.

E. Sternberg, USA

398. Mossakowski, J., Singular solutions in the theory of orthotropic plates (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **6,** 413–432, 1954.

A. Pucher [*Ing.-Arch.* **12,** 76–100, 1941] introduced influence surfaces for solutions of isotropic plates. Equations of influence surfaces coinciding in case of plates with deflection functions consist in Pucher's method of two terms. The first term is a deflection function of an infinite plate: the second is a function formed of biharmonic polynomials whose coefficients must be determined so that this function satisfies boundary conditions. Pucher's method could not be applied to orthotropic plates because the influence function of an infinite orthotropic plate was unknown. The author's object was to extend Pucher's method to orthotropic plates. He solves the differential equation of deflection of orthotropic plates in a closed form and finds influence surfaces of an infinite plate. Using this solution he solves in addition three different support cases of a semi-infinite plate loaded by a concentrated force. After setting $E_x = E_y = E$, author's solutions reduce to the well-known solutions of isotropic plates.

T. Leser, USA

399. Lehnickiĭ, S. G., The stress distribution in an anisotropic plate with an elliptic elastic core (plane problem) (in Russian), *Inzhener. Sbornik, Akad Nauk SSSR* **19,** 83–106, 1954.

Author solves the problem for infinite plates using a perturbation method, based on the solution for the homogeneous infinite plate loaded uniformly at infinity. The special cases considered comprise a circular core in orthotropic plates under uniaxial and biaxial tension and shear, an elliptic core in a plate subject to stresses varying linearly with the rectilinear coordinates, a circular core in a plate in uniform bending.

J. R. M. Radok, USA

400. Tremmel, E., Contribution to the problem of thermal stresses in disks (in German), *Anz. Akad. Wiss. Wien* **90,** 1, 247–251, Jan. 1953.

Two-dimensional field under consideration is assumed to have curves enclosing heat sources. Temperature $T(x, y)$ is split up in $T_0 + T_1$, where only T_1 will give multivalued temperature displacements. Comparing displacements from Airy's stress-function ψ with temperature displacements, a differential equation is given for that part ψ_1 of ψ which cancels the multivalued temperature displacements. Following Muskhelishvili, author shows how a particular integral for ψ_1 can be obtained.

W. L. Esmeijer, Holland

Experimental Stress Analysis

(See also Revs. 381, 438, 465)

401. Ockleston, A. J., Load tests on a three story reinforced concrete building in Johannesburg, *Struct. Engr.* **33,** 10, 304–322, Oct. 1955.

402. Pengelley, C. D., Dower, E. J., and Lemcoe, M. M. Structural model studies of concrete slab foundations, *J. Amer. Concr. Inst.* **26,** 10, 961–976, June 1955.

The theory of dimensional analysis was applied to the design of reinforced-concrete structural models of small home foundation slabs. Methods of fabricating satisfactory models were developed. Static stiffness measurements are reported on six different designs of the same cost and size. Two full-scale foundations were tested corresponding to a pair of the model designs, and model and full-scale results are compared.

From authors' summary by W. G. Shockley, USA

403. Vogt, H., The statics treatment of oblique bridges (in German), *Ingenieur* **67,** 8, 15–21, Feb. 1955.

Calculation of stresses in oblique plates or plate girder bridges is very difficult, especially considering the end parts. Therefore author deals with an experimental method, using as test material a very appropriate synthetic substance named "Trovidur." He gives a detailed description of execution of test models and manner of testing. By measuring change of deflection (curvature) in various directions, it is easy to calculate the principal bending moments. A single difficulty is that Trovidur possesses twice the Poisson ratio in comparison to concrete. Author states that he is investigating how to eliminate this divergence by a special treatment of model material.

Reviewer points out that the explained test method, using models of Trovidur, may be considered as a very important help for stress analysis in two- or three-dimensional structures.

H. Beer, Austria

404. Jessop, H. T., Snell, C., and Jones, J., Results of photoelastic investigation of stresses in a tension bar with unfilled hole, *J. roy. aero. Soc.* **59,** 529, 64–65, Jan. 1955.

Concerning the effect of the ratio of hole diameter to width of bar upon the stress distribution, tests were made upon a standard-size bar with four different sizes of holes, and the stress distribution on the cross section of the bar through the hole center was explored for the four cases.

From authors' summary

405. Föppl, L., A new evaluation method in two-dimensional photoelasticity (in German), *ZAMM* **34,** 12, 454–459, Dec. 1954.

A formula is derived expressing the sum of the two principal stresses at any point as an integral of the principal-stress difference and of its derivatives along the lines of principal stress. (These quantities can be determined experimentally from the isoclines and the isochromats.) The integration path is arbitrary; from any point on the model where the principal-stress sum is known, to the point where it is to be determined. Integration along several paths gives improved accuracy. From their sum and difference, the principal stresses can immediately be deduced.

A second formula gives the average stress round the perimeter of a hole as an integral of the principal-stress difference round the perimeter. R. L. Wooley, Iraq

406. **Post, D., Multiple beam sharpening of photoelastic fringes,** *J. appl. Phys.* **25,** 8, 1060–1061, Aug. 1954.

A technique is presented for transforming the variation of intensity of photoelastic fringes so that the peaks are more sharply delineated without any shift in their positions. This effect is achieved by placing partial mirrors of high reflectivity on both sides of the model in a standard circular polariscope.
W. Shelson, Canada

407. **Flanagan, J. H., Simplified calibration of photoelastic models,** *Prod. Engng.* **25,** 7, 201, 203, July 1954.

408. **Pustynnikov, V. G., Device for solving the equations of the ellipse of deformation (ellipsometer)** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **19,** 161–166, 1954.

Relating to the use of strain rosettes of various types, a device is described which permits the direct measurement of the shear strain in various desired directions. The gages of the rosette, in pairs, form two of the legs of a Wheatstone bridge, which also includes a special potentiometer whose resistance is made proportional to either the sine or the cosine of twice the desired direction angle. As a result, each such Wheatstone bridge directly computes the difference of the strains of the two incorporated gages, times either the sine or the cosine of the above angle. For four-gage rosettes, the shear strain is obtained as the sum of two such terms. Consequently, two such Wheatstone bridges are employed which are connected in series to give the desired shear strain. G. Winter, USA

Rods, Beams, Cables, Machine Elements

(See also Revs. 363, 379, 383, 388, 404, 440, 445, 452, 454, 616)

409. **Dudley, D. W., Practical gear design,** New York, Toronto, London, McGraw-Hill Book Co., Inc., 1954, x + 335 pp. $7.

A particularly valuable book on the many considerations going to make up a successful gear design. The author's experience is reflected in the wealth of quantitative information on current practice in design and manufacture and in methods of making preliminary estimates of gear size and machining time. Book consists of eight chapters as follows: (1) Gear-design trends, including a wide range of types and qualities. (2) Preliminary design considerations—the Lewis and Hertz stresses, scoring factor, quick estimate of gear size, data required on drawings. (3) Design formulas—involute trigonometry, standard and altered tooth proportions, gear-rating practice following and amplifying the methods of AGMA, Gleason Works, and others. (4) Gear materials—physical properties, heat treatments, uses. (5) Gear manufacturing methods—commonly used methods, sizes, and capacities of available machines, design limitations of methods, time required. (6) Design of tools to make gear teeth—relationship of tooling to design, adaptation of design to existing tools and vice versa. (7) Gear failures—discussion of various methods of gear failure, gear mounting, and lubrication problems. (8) Special design problems—nonstandard center distances, combined bending and torsion of wide-face gears, high-speed gearing.

This book is recommended to all who design gears as a very useful addition to the existing literature.
D. K. Wright, Jr., USA

410. **Parkes, E. W., The stresses in a built-up girder subjected to a concentrated load,** *Proc. roy. Soc. Lond.* (*A*) **231,** 1186, 379–387, Sept. 1955.

Paper analyzes stresses in uniform built-up girder consisting of web of constant thickness elastically connected to two similar flanges. Flanges are assumed to obey Bernoulli-Euler theory and web is treated as problem in plane stress. Method can be used for any flange loading, but particular attention is limited to a single concentrated load applied to one flange. Satisfactory agreement is reached with an experimental investigation.
From author's summary by H. D. Conway, USA

411. **Kolodner, I. I., Heavy rotating string—A nonlinear eigenvalue problem,** *Comm. pure appl. Math.* **8,** 3, 395–408, Aug. 1955.

Steady rotation of a heavy string with one free end point is considered. In linearized case corresponding to small velocity of rotation, differential equations of motion are reduced to Bessel equation of first order. Hence, eigenvelocities of rotation exist in this case, fixed by zeros of Bessel function of zero order; in particular, minimum velocity of steady rotation exists. Latter feature is exhibited by nonlinear eigenvalue problem corresponding to large velocity, but any velocity above the minimum is permitted in this case. Extensive discussion of the nonlinear eigenvalue problem is given. J. J. Gilvarry, USA

412. **Bartlett, R. J., Bending and axial stresses in circular columns,** *Concr. constr. Engng.* **50,** 8, 293–297, Aug. 1955.

This note describes a method of analyzing the stresses in a circular reinforced-concrete column in which tensile stresses are caused by a bending moment M combined with an axial load.
From author's summary

413. **Chilver, A. H., Average warping in the torsion of thin-walled open-section beams,** *J. Mech. Phys. Solids* **3,** 4, 267–274, July 1955.

Author develops equations for the nonuniform torsion of a beam of thin-walled open cross section. Since the angle of twist varies along the length of the bar, free warping of adjacent cross sections is hindered and longitudinal normal stresses are set up in the material. An expression for these stresses is developed, which is shown to satisfy all conditions of equilibrium, in terms of the varying rate of twist and an average longitudinal warping defined as a mean value taken over the whole area of the cross section.

The results are compared with those of Timoshenko [*J. Franklin Inst.* **239,** nos. 3, 4, 5, 1945], in which he defines a similar average longitudinal warping as a mean value taken over the central line of the cross section rather than over the whole area. The author contends that Timoshenko's result is accurate only if the cross section has a uniform thickness, and this reviewer agrees. W. O. Richmond, USA

414. **Heilig, R., Theory of heavy unelastic ropes** (in German), *Stahlbau* **24,** 6, 133–135, June 1955.

A method of approximation is presented which takes into account the influence exerted upon the balance of moments at the nonelongated rope element by the horizontal displacements as measured from the center line of the weightless rope which is exclusively loaded by useful load (s). This method permits the horizontal pull to be determined with great accuracy, whereas the rope curve is not obtained, the latter being calculated with the aid of another method of approximation.
From author's summary by G. Sonntag, Germany

415. Davidsson, W., Investigation and calculation of the remaining tensile strength in wire ropes with broken wires, *Acta Polyt.* **174** (Mechanical Engineering Series **3**, no. 6), 38 pp., 1955.

The remaining tensile strength P_{ds}, as estimated by static tensile test of a straight rope, is not adequate to serve as a starting point for judging whether a rope should be discarded or not. In this respect the remaining bending tensile strength P_{bdr}, which is obtained by bending the rope over a pulley when in movement and under a load, should be decisive. For ropes with two layers of wires in the strands, covered by the investigation, $P_{bdr}/P_{ds} \approx 0.78$ may be set in the case of moderate weakening owing to wire breaks and wear.

The wire recovery length has been investigated in static remaining tensile strength tests. Here, among other things, it is proved that the wire recovery length is not equally great for the different layers of wire in the strands. Thus for ropes with two layers of wires in the strands the wire recovery length in the inner layer was only about half that of the outer one.

A method is given for calculating the weakening due to wire breaks and wear of the tensile strength of a rope which is still in use.

Some fifty discarded crane, lift, and telpher ropes have been investigated with regard to the occurrence and distribution of invisible wire breaks.

Finally, the advisability of choosing the rope lay as the control length is pointed out. From author's summary

416. Reissner, E., On torsion with variable twist, *Öst. Ing.-Arch.* **9**, 2/3, 218–224, 1955.

Interesting theoretical treatment of torsional center of cylindrical shafts, subjected to variable twist, by means of variational method. The effect of restraint against warping is treated in this connection.

Variational equations for stresses and displacements, previously published by the same author, are being used. Saint Venant theory for uniform twist is being utilized, together with determination of center of twist by P. Cicala and the L'Hospital rule. C. R. Bell, USA

417. Cadambe, V., and Kaul, R. K., Torsional rigidity of narrow bars and tubes of twisted shape, *J. sci. indust. Res., India* **13**, 10, 673–677, Oct. 1954.

It is well known that, in a straight narrow section with a comparatively large angle of twist, the normal stress will contribute an important portion of the torque, varying as third power of the angle of twist. Authors extend the solution to a section with an initial angle of twist. Two expressions of torque are obtained for solid and thin-walled sections. Several examples are given demonstrating that the effect of normal stress on torque is much more predominant in a solid section than in a hollow one, and the increase of torsional rigidity depends on the initial angle of twist. The results will have application in analyzing turbine blades, propellers, bourdon tubes, etc. D. H. Cheng, USA

418. Tekinalp, B., Large elastic deflections of plane rods, *Bull. tech. Univ. Istanbul* **7**, 7, 35–49, 1954.

Author formulates the differential equations of elastic deformation of curved beams in terms of two unknown functions A and B, which are, respectively, the cosine and sine of the angle between the tangent vectors on deformed and undeformed beams. This set of nonlinear equations is solved by method of small perturbation in terms of a nondimensional parameter α, which is inversely proportional to the bending rigidity EI. Two illustrative examples are given. T. H. H. Pian, USA

Plates, Disks, Shells, Membranes

(See also Revs. 380, 394, 396, 397, 398, 399, 403, 413, 431, 437, 438, 440, 445, 543)

419. Yu, Y.-Y., On the complex representation of the general extensional and flexural problems of thin plates and their analogies, *J. Franklin Inst.* **260**, 4, 269–282, Oct. 1955.

Paper constitutes a generalization of the complex variable method developed by Muskhelishvili and Lechnitzky for solving the extensional and flexural problems of thin plates to include, respectively, the effect of the body force and the lateral load. The two usual analogies between the two types of problems are also established in a quantitative manner for these general cases, and, as was observed by Southwell, the two analogies may be combined into one with the reversal of the sign of Poisson's ratio. As illustrations, several circular plate problems are solved by means of the generalized boundary equations derived, and the corresponding analogous problems of some of these are determined by means of the analogies.

As a necessity, a relation is established first between the indefinite integral and the line integral of a nonanalytic function in the complex plane.

From author's summary by D. Williams, England

420. Hodge, P. G., Jr., Impact pressure loading of rigid-plastic cylindrical shells, *J. Mech. Phys. Solids* **3**, 3, 176–188, Apr. 1955.

Work reported is continuation of previous investigations by the same author [AMR **8**, Rev. 1665]. Maximum shearing stress criterion (Tresca) for yielding is accepted. A simplified yield domain is introduced; a point with rectangular coordinates equal to the bending moment and to the circumferential stress resultant (both in suitable nondimensional units) must lie within or on the boundary of a square; the axial strain resultant is zero. Elements on the shell for which the point defined falls on the boundary undergo plastic deformation; if the point falls within the square, the element remains rigid. A typical bay (length = $2L$) of an infinite cylindrical shell (diameter = $2a$, wall thickness = $2h$), reinforced by equally spaced rigid rings and loaded by a rectangular finite external pressure pulse, is investigated. A solution is suggested intuitively; it satisfies the equation of motion, the yield condition and inequalities concerning the strain rates for "short" shells ($c^2 = L^2/ah < 6$) and "medium" loads (pressure greater than collapse pressure, but less than $(6 + c^2)/(2 + c^2)$ times collapse pressure). The solution is then modified to suit "long" shells and "high" loads. In every case movement continues after removal of load until kinetic energy is absorbed by plastic work. Expressions for stress resultants, velocities, displacement are given for each case; typical results, presented graphically, demonstrate that calculated final displacements can be several times larger than those at end of pressure pulse. Instability is not investigated. G. Sved, Australia

421. Mansfield, E. H., and Kleeman, P. W., A large-deflexion theory for thin plates: A theory based on the assumption of an inextensional middle surface of the plate, *Aircr. Engng.* **27**, 314, 102–108, Apr. 1955.

Paper presents an unconventional method for determining large elastic deflections of transversely loaded thin plates when the loading is resisted primarily by bending action. The middle surface of the plate, if inextensional, deforms into a developable surface, the generators of which are to be determined. Assuming that the total bending moment acting about a generator is determinant, the associated strain energy of bending is expressed in terms of applied loads and the unknown distribution of generators, which is the nfound by maximizing the strain energy integral for the plate.

Solutions are developed for (a) tip-loaded cantilever plates of triangular planform, (b) long thin strips subjected to terminal bending moments, (c) square plates loaded at the corners by equal and opposite pairs of forces. Experimental tip deflections for (a) fall between values of present theory and larger values of small-deflection theory; solution (b) shows good agreement with results of exact large-deflection theory; predictions in case (c) of small-deflection theory and present theory for relative deflection of adjacent corners are in the ratio $2/(1 - \nu)$, between which extremes experimental values for plates of various side/thickness ratios are distributed.

Reviewer believes method provides a more accurate determination of total strain energy of bending in cases such as (a) and (b) than in cases such as (c) where the principal curvatures of the deformed middle surface are of comparable magnitude.

L. Maunder, USA

422. Parkus, H., Stresses in an oblique circular conical shell (in German), *Öst. Ing.-Arch.* **9,** 2/3, 196–199, 1955.

Generalized theory for thin shells previously derived by author [title source, **4,** 160–174, 1950; **6,** 30–35, 1951; AMR **4,** Rev. 629; **5,** Rev. 1667] is extended to special case of an oblique conical shell.

O. K. Mawardi, USA

423. Csonka, P., On shells generated by translation surfaces (in Hungarian), *Magyar. Tud. Akad. Oszt. Közl.* **15,** 1/2/3/4, 333–345, 1955.

The shell is formed by sliding generator curve $Z = f_1(x)$ along line $Z = f_2(y)$; hence height of shell at point (x, y) is $f_1(x) + f_2(y)$. Both shell and loading have two planes of symmetry; area covered is rectangular (dimensions $2a \times 2b$). Membrane stresses only are considered; the stress resultants are expressed in terms of a stress function (similar to Airy's). It is shown that, provided the load function is the sum of two power series—one in x, the other one in y—then $f_1(x)$ and $f_2(y)$ can be determined so that the stress function should have the simple form $(a^2 - x^2)(b^2 - y^2)$. Two special cases are treated in detail; first, load per projected unit area constant; second, load increases with square of distances from planes of symmetry.

G. Sved, Australia

424. Mayers, J., and Budiansky, B., Analysis of behavior of simply supported flat plates compressed beyond the buckling load into the plastic range, *NACA TN* 3368, 44 pp., 1955.

The plate chosen for study is a simply supported square sandwich plate which buckles in the elastic range. All edges are assumed constrained to remain straight. A large deflection postbuckling analysis is based upon the variational principle for deformation theory of plasticity which is the equivalent of the minimum potential energy theorem of elasticity. The minimum is not at all sharp so that computations were performed on the SEAC using a modified steepest descent procedure, but in some cases convergence was still unsatisfactory. Coefficients in all of a double trigonometric expansion of the components of displacement were varied. As explained by the authors, the total difference in energy between the first cycle of iteration based on elastic displacement coefficients and the last cycle was extremely small, about 1%. The accurate determination of stress requires the lengthy minimization.

D. C. Drucker, USA

425. Sokolowski, M., Application of the perturbation method to plate problems (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **5,** 415–436, 1953.

The perturbation method was introduced by H. Poincaré ["Leçons de mécanique céleste," Gauthier-Villars, Paris, 1905] to find approximate solutions of differential equations. It permits one to solve eigenvalue and boundary-value problems differing slightly from well-known and already solved cases. As a special case of the perturbation method, a one-parameter eigenvalue problem was presented in detail by L. Collatz ["Eigenertaufgaben mit technischen Anwendungen," Akademische Verlagsgesellschaft, Leipzig, 1949; see AMR **3,** Rev. 2152]. The theory given by author is based on Collatz's monograph. The author applies the method to stability problems of isotropic and orthotropic rectangular plates compressed nonuniformly along opposite edges. He compares his results with exact solutions and shows that the error is negligible. The method simplifies considerably in case of simple boundary-value problems without eigenvalues.

T. Leser, USA

426. Ambarcumyan, S. A., On the computation of long shells of double curvature (in Russian, with Armenian summary), *Akad. Nauk Armyan. SSR Izv. Fiz.-Mat. Estest. Nauk* **6,** 5/6, 65–68, 1953.

Author considers a very sloping shell (a sloping shell is an open shell of small curvatures) which is made up of orthotropic layers. Solutions for such a shell are obtained from a system of two differential equations given by the author in his previous (unavailable) publications. In case of a long shell (the exact definition of a long shell must be also in the author's previous publications), the system of differential equations simplifies considerably and reduces to the one given by V. Z. Vlasov ["General theory of shells," Gostehizdat, Moscow-Leningrad, 1949]. The author makes one more simplifying assumption that the Poisson ratios are zero and solves the system for a long cylindrical sloping shell curved in the longitudinal direction. For a homogeneous isotropic shell the solution reduces to the one given by V. V. Novožhilov ["Theory of thin shells," Gostehizdat, Moscow-Leningrad, 1951] and the author concludes that Novožhilov's theory and Vlasov's theory are coincident.

T. Leser, USA

427. Brock, J. E., Matrix analysis of piping flexibility, *J. appl. Mech.* **22,** 3, 361–362, Sept. 1955.

See AMR **8,** Rev. 2701.

428. Klein, B., Parameters predicting the initial and final collapse pressures of uniformly loaded spherical shells, *J. aero. Sci.* **22,** 1, 69–70, Jan. 1955.

Note in Readers' Forum.

429. Glausser, W. E., and Cartright, J. A., Design-features in heat-exchangers, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-62, 22 pp.

Buckling Problems

430. Allen, H. G., The estimation of the critical load of a braced framework, *Proc. roy. Soc. Lond.* (*A*) **231,** 1184, 25–36, July 1955.

The problem considered is the determination of the load that will cause elastic buckling of a triangulated framework without joint translation. Author outlines an elimination method for solving the slope-deflection equations for the structure under a given loading. The method involves the replacement of each triangle of the structure in turn by a single hypothetical member of equivalent stiffness. The structure is eventually reduced to one member, whose stiffness indicates whether or not the origi-

nal structure is stable under the given loads. The value of the critical load can be approached by successive applications of the method. J. W. Clark, USA

431. Bijlaard, P. P., On the buckling of stringer panels including forced crippling, *J. aero. Sci.* **22, 7,** 491–501, July 1955.

Analysis considers effective moment of inertia of stiffeners when located on one side of plate and effective width of plate at unloaded edges. It is shown that rigid beam webs supporting unloaded edges of plate greatly increase effective width for first stiffener. Effects of shear deformation of stiffener web and flexibility of attached stiffener flange may each cause approximately 10% reduction in effective moment of inertia in case of predominantly column-type deflection of stiffeners. Explicit formula is presented for critical buckling stress in forced crippling mode, valid for arbitrary number of stiffeners. Rapid method for computing buckling stress is given.

From author's summary by G. Housner, USA

432. Sahmel, P., Approximative calculation of buckling length of multistoried frames (in German), *Stahlbau* **24,** 4, 89–94, Apr. 1955.

Paper treats the calculation of the buckling lengths of rectangular portal frames of perfectly elastic material, sidesway being permitted. The bases of all ground floor columns are supported in the same manner. Stiffness of the columns varies from story to story. Column bases may be hinged, or perfectly or elastically built-in. The energy method, namely, the approximate calculation of M. G. Puwein [title source, **11,** 14/15, 118–120, July 1938], is applied for the determination of the buckling length of the columns. As virtual deformation, a system of translations produced by a horizontal thrust force is introduced, but instead of the actual moment diagram, a simplified diagram is made use of. This diagram meets conditions of stability but does not satisfy those of continuity. Numerical examples support the utility of this diagram.

Results thus obtained are compared to those of original Puwein method and to values calculated by DIN 4114. In the presented examples the simplified moment diagrams deviate but little from actual graphs, and the error is comparatively slight. If, however, the actual and the simplified moment diagrams differ appreciably—for instance, if the frame columns are relatively rigid compared to beams—greater errors are possible. The approximate formulas for routine design presented in the paper substantially reduce calculatory work in the stability analysis of frames and are a useful tool for structural engineering practice.

P. Csonka, Hungary

433. Warren, C. H. E., and Fraenkel, L. E., A combination of the quasi-cylinder and slender body theories, *J. roy. aero. Soc.* **59,** 532, 305–308 (Technical Notes), Apr. 1955.

434. Murray, J. M., Corrugation of bottom shell plating, *Trans. Instn. nav. Arch. Lond.* **96,** 3, 229–267, July 1954.

Paper deals with the buckling of the shell plating of transversely framed ships. An attempt is made to describe the mechanism of buckling and to develop a theoretical approach; however, the effect of initial out-of-flatness of the shell plates is neglected. Although buckling of the plating of riveted ships has been observed, the weakness in the case of welded ships and the difference in behavior of the plates are ascribed to the welding rather than the greater degree of unfairness present in welded ships as compared to riveted ships.

Reviewer believes author overlooks the use of thicker plating or closer spacing of transverse frames as a means of increasing the structural strength of the hull. Buckling tests of plates were made under the aegis of the British Shipbuilding Research Association, and some of the results are given.

Discussions by twenty-one members of the Institution are presented. Marshall Holt, USA

435. Naleszkiewicz, J., The quantization of the phenomena of elastic instability. I (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **6,** 3–32, 1954.

In this paper "quantization" has no connection with Planck's quantum of energy. Different states of elastic equilibrium for the same external load occur at energy levels which differ by constant quantities. These constant energy differences the author calls quanta. He introduces a very simple model of an elastic system requiring only elementary mathematical tools. He investigates for his model various positions of stable equilibrium and the loss of stability and shows the existence of different states of equilibrium for the same loads. He studies the potential energy of the system in order to explain why in practice there is only one position of stable equilibrium: the others are difficult to obtain, although mathematically they are also stable. The position of equilibrium occurring in practice corresponds not only to a local minimum but also to the least of all energy levels. This state of equilibrium is called absolutely stable. To raise the system from one state of equilibrium to the next one, it is necessary to introduce an additional quantum of energy.

T. Leser, USA

436. Naleszkiewicz, J., The quantization of the phenomena of elastic instability. II (in Polish, with Russian and English summaries), *Arch. Mech. stos.* **6,** 261–290, 1954.

This paper is a continuation of previous one (see preceding review). In the first paper, author studied, on a simple model of an elastic system, various states of equilibrium at different energy levels. In this paper, he studies a more complicated model of a bar with uniform cross section loaded by an axial force, a torque, and a bending moment. The system of differential equations controlling such a model was derived by A. Grzedzielski and J. Nowiński ["Calculations of three-bar pyramids," Sprawozd. Inst. Techn. Lotn. **4/26,** 1938]. Author introduces certain simplifying assumptions and solves the system, obtaining two expressions for deformations. For a beam in a critical state these expressions represent two different criteria for stability which depend on the torque. In the absence of torque they have different forms than those containing torque. The former case corresponds to a lower energy level; the latter to a higher one. The example shows that in systems not as simple as the one discussed in the first paper the question of energy levels may become quite intricate. T. Leser, USA

437. Grigoliuk, E. I., Stability of a closed, double-layer conical shell under action of uniform normal pressure (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **19,** 73–82, 1954.

The question is about thin-walled double-layer shells of elastic, isotropic material, when both layers have the same Poisson ratio.

Author begins by recapitulating and also criticizing former results obtained in this field by A. Pflüger, F. J. N. Niordson, R. v. Mises, and others. Then he writes the complicated expression for the total potential energy of the shell in terms of displacements, which are chosen so as to satisfy the kinematic boundary conditions. Applying the energy method leads in the usual way to a very complicated general formula for the critical value of the pressure.

Numerical results are obtained for the value 0.3 of the Poisson ratio both in the case of a homogeneous (i.e., one-layer) and a

double-layer shell. Detailed numerical tables are suitable for technical use.

Paper is doubtless a valuable contribution to solving, by means of linearized theory, difficult problems connected with the buckling of thin-walled shells. V. Vodička, Czechoslovakia

438. Wenk, E., Jr., Slankard, R. C., and Nash, W. A., Experimental analysis of the buckling of cylindrical shells subjected to external hydrostatic pressure, *Proc. Soc. exp. Stress Anal.* **12, 1, 163–180, 1954.**

Structures

See also Revs. 394, 401, 402, 403, 412, 421, 423, 430, 432, 456, 462)

439. Kuenzi, E. W., Mechanical properties of aluminum honeycomb cores, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1849, 18 pp., 3 tabs., 33 figs., Sept. 1955.

Report presents the results of tests of commercially produced aluminum honeycomb cores for use in structural sandwich construction. Detailed descriptions of core materials and testing procedures are given. Analyses of experimental data include methods for predicting average strength and stiffness values from basic material properties and core configuration. Included are results of flexure tests of sandwich and an analysis of the data for determining core properties from such tests.

Design values of core properties, based on tests of commercial core samples, are presented in tabular form and as stress-strain curves. From author's summary

440. Roberston, R. G., Design charts for prestressed rectangular beams and slabs, *Proc. Instn. civ. Engrs.* **4,** part 3, 1, 151–173, Apr. 1955.

441. Moore, J. H., Determining the required thickness of concrete pavements for highways, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. 596, 21 pp., Jan. 1955.

442. Shevelev, B. N., Summary of experience in construction and operation of an earthfill dam (in Russian), *Gidrotekh. Stroit.* **24, 2,** 33–37, 1955.

A big hydraulic fill dam was built across Volga River at Rybinsk (Shcherbakov) in 1941. It is 1600 ft long, 108 ft maximum height, 920 ft maximum bottom width; earth volume is about 2.4 million cu yd. Dam was built on pervious foundation without any core or screen. After 13 years of operation the sand has settled finally and the dam is well compacted; seepage is normal. After the reservoir was filled to 85-ft level and 1750 sq miles of area, many peat swamps emerged as floating islands and, in 1951, endangered the dam. Peat jams were destroyed by blasting of 35 tons of explosives to prevent clogging of spillways and overflow over the dam. Dam withstood such an unusual test without damage. S. Kolupaila, USA

443. Atkinson, R. J., Permissible design values and variability test factors, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2877, 20 pp., July 1950, published 1955.

For the design of structural elements it is postulated that (*a*) not more than 10% to any given design should have strength below the design value, (*b*) not more than 0.1% should have strength below 90% of the design value. This rule forms a working basis for the interpretation of tests on statistical lines.

On the basis of a fixed probability, part I deduces: (1) Expressions for the derivation of permissible design values from a given number of test results; (2) the number of test results required, on specimens chosen at random, so that the estimates of permissible design values can be regarded as sufficiently accurate; and (3) the factor which should be applied to the results of tests on any number of similar components designed to meet a specified requirement.

The effects of different probabilities and of different acceptable proportions of weak specimens are investigated in part II. From author's summary

444. Grime, G., and Giles, C. G., The skid-resisting properties of roads and tyres, *Instn. mech. Engrs. Auto. Div.* no. 1, 19–30, 1954–55.

445. Yusuff, S., Theory of wrinkling in sandwich construction, *J. roy. aero. Soc.* **59,** 529, 30–36, Jan. 1955.

If the thickness of the core is regarded as finite, the wrinkling stress is given by a square root formula consisting of Young's moduli of the materials and the ratio of the thickness of the face and core. Alternately, if shearing stresses in the core are considered and the face is supported by a sufficiently thick or a semi-infinite medium, the wrinkling stress is given by a cube root formula which consists of the moduli of the materials but indirectly depends upon the geometry of the structure. This formula is valid only if the thickness of the core is greater than the marginal zone of the distortions in the core. The width of this zone is thus useful as a criterion which discriminates between the two cases of wrinkling. The theory is compared with previous works and is in satisfactory agreement with available test data. G. Gerard, USA

446. Nitsiotas, G., Creep and shrinkage in statically indeterminate concrete structures with bearing parts of steel (in German), *Ing.-Arch.* **22, 5,** 323–335, 1954.

Influence of creep and shrinkage upon properties of structures containing bearing parts of steel and concrete can always be calculated with the aid of a system of first-order differential equations. Solution is based on "creep integral" developed from a formula by F. Dischinger [*Bauingenieur* **20,** p. 54, 1939] for the "free" deformation of concrete. (A deformation is "free" if it does not produce any reaction.) B. Gross, Brazil

447. Nowacki, W., The statics of flat gridwork systems (in Polish, with Russian and English summaries), *Rozprawy Inz.*, 143–187, 1954.

Author defines a flat gridwork system to be a flat system of frames loaded by forces perpendicular to the plane of the system and/or by moments whose vectors lie in the plane of the system. As a rule, such a structure is statically indeterminate and the most suitable method to solve it is the deformations method which is used by the author. He outlines a solution procedure in a general case, analyzes in more detail the case of curved and broken-line bars, solves special cases of gridwork systems common in building practice, and presents a theory of gridwork systems on elastic foundations. T. Leser, USA

448. Sdobyrev, V. P., Criteria of stiffness of plane and spatial systems (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **15,** 187–190, 1953.

The distribution of stresses in a framed structure is determinate if there are no redundant constraints. The addition of constraints makes the structure stiffer. This paper defines a criterion of stiffness in terms of the number of excessive constraints. This is expressed directly in terms of the types and the numbers of members and connections. Another expression of his criterion

is in terms of the number of elementary regions in the graph of the structure and the reduced number of intersections. Examples are given as illustrations for both plane and spatial structures.

M. Goldberg, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 390, 420, 424, 469, 470, 579)

449. Weltmann, R. N., and Kuhns, P. W., An automatic viscometer for non-Newtonian materials, *NACA TN* 3510, 34 pp., Aug. 1955.

A concentric-cylinder rotational viscometer is described that is capable of recording meaningful flow curves of rate of shear against shearing stress for most non-Newtonian materials. For many of these materials the flow curve depends on the flow condition of measurement; that is, on the rate of change and the magnitude of the applied flow parameter, which is the rate of shear in this viscometer. Therefore, this instrument incorporates features that permit the operator to program the flow conditions, which are used to produce the flow curve. The instrument is designed so that for most materials the rate of shear is proportional to the rotational speed. A program feature permits presetting the maximum rotational speed to any speed from 80 to 1600 rpm. The speed is automatically varied. The acceleration is constant and can be selected, so that 15, 30, 60, 120, or 240 sec are required for the speed to change from zero to the preset maximum. Ranges of increasing and decreasing speeds can be programmed to follow each other in two different sequences. The viscometer can also record shearing-stress changes as a function of time at given constant rates of shear.

Rates of shear up to 4000 sec^{-1} can be obtained under laminar flow conditions. The instrument is built to measure shearing stresses from 50 to 250,000 dynes/cm^2. Viscosities up to 3000 poises can be measured automatically, and up to 20,000 poises manually. Friction is kept at a minimum to permit viscosity measurements down to 0.05 poise.

The coaxial alignment of the two cylinders is mechanically fixed. The annuli between the cylindrical surfaces are designed to give (1) maximum shearing stresses for any given motor torque, (2) less than 15 % variation in shearing stress across their width, and (3) minimum increase in shear temperature during operation. End effects are minimized by the design so that they can be neglected. Accessories are incorporated to keep the shear volume of the material constant and confined. A constant-temperature bath is provided. The instrument can be readily modified for dynamic flow measurements up to frequencies of 4 cps. Flow curves, time-torque curves, and dynamic viscosity data are presented to demonstrate the versatility of the viscometer.

From authors' summary

450. Lee, E. H., Stress analysis in visco-elastic bodies, *Quart. appl. Math.* **13,** 2, 183–190, July 1955.

The application of the Laplace transform is attempted for greater utilization of the extensive literature on the theory of elasticity in the analysis of stress and strain in linear viscoelastic bodies. The analysis is considered when the loading is quasi-static so that inertia forces due to the deformation are negligible.

Although the removal of the time variable by applying the transform enables the solution to be obtained in terms of an associated elastic problem, the operation may completely modify the spatial distribution in the associated problem.

However, for proportional loading, in which the space and time variations of the prescribed quantities separate, the spatial distribution is maintained in the associated problem. A simple example in which a vertical point force acts normally at a fixed point on the surface of a semi-infinite viscoelastic body is given for this. As a problem which is not in this category, a convenient method of treating moving surface tractions is also demonstrated.

H. Mii, Japan

451. Pope, J. A., and Mohamed, A. K., Residual plastic strains produced by single and repeated spherical impact, *J. Iron Steel Inst. Lond.* **180,** part 3, 285–297, July 1955.

Aim of the work was to investigate, theoretically and experimentally, the maximum plastic strain and its penetration below the surface of a metal, resulting from single and repeated spherical impact. The variables studied were the velocity, the energy, and the diameter of the indenter. The distribution of the plastic strain below the indentation was examined by making hardness measurements on appropriately prepared sections through the center of the indentations.

From authors' summary by J. C. Fisher, USA

452. Cotter, B. A., and Symonds, P. S., Plastic deformations of a beam under impulsive loading, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 675, 1–20, Apr. 1955.

The distortions of a uniform free-free beam subjected to a certain symmetrical distribution of initial transverse velocity are calculated on the basis of a plastic-rigid analysis. Detailed analysis is made of the several stages of deformation, involving various zones of plastic distortion along the beam, which are found to precede the ultimate rigid-body motion at constant velocity. Comparison is made with the results of Bleich and Salvadori [AMR **7,** Rev. 1418] who considered the same problem on the basis of both elastic-plastic and rigid-plastic analyses, but who assumed a single plastic hinge at the beam midpoint.

B. Budiansky, USA

453. Pöschl, Th., A dimensionless number for the description of flow condition of solid bodies (in German), *Öst. Ing.-Arch.* **9,** 1, 22–24, 1955.

A viscoplastic solid is considered that remains rigid until the yield stress is reached and then deforms with a strain rate that depends linearly on the excess of the actual stress over the yield stress. It is shown that the states of plastic flow in this solid are characterized by a dimensionless number, the product of the viscosity and a characteristic speed, divided by the product of the yield stress and a characteristic length. (The reciprocal of this number is called "Bingham number" in this reviewer's contribution to the "Treatise on rheology," vol. 1, Academic Press, New York, 1955, p. 95.)

W. Prager, USA

454. Čobanyan, K. S., Stability of the plane form of bending beyond the elastic limit for an arbitrary law of hardening (in Russian, with Armenian summary), *Akad. Nauk Armyan. SSR. Izv. Fiz.-Mat. Estest. Tekh. Nauk* **6,** 4, 1–20, 1953.

The critical length of a beam rendered partly plastic due to bending in a plane of symmetry is computed from the current torsional and flexural rigidities of the yielded section. The stress-strain law used is the small elastic-plastic deformation (total strain) form of Ilyushin ["Plasticity," part I, OGIZ, Moscow-Leningrad, 1948] and the velocity distribution is assumed to be the same as that of the wholly elastic beam. Numerical values are given for the rectangular beam and for an I-beam. Author seems unaware of the work of Neal [*Phil. Trans. roy. Soc. Lond.* (A) **242,** 197–242, 1950; AMR **3,** Rev. **2617**] who, incidentally, uses a more precise expression for the critical length, based on H. Reissner [*S.-B. Berlin. Math. Ges.* **3,** 53–56, 1904].

R. M. Haythornthwaite, USA

455. **Fastov, N. S., On the equations of the theory of plasticity taking account of temperature variation** (in Russian), *Dokl. Akad. Nauk SSSR.* (*N.S.*) **85**, 67–70, 1952.

In the presence of temperature change, the ratio of the deviators of stress and strain, which in the total strain law of Ilyushin ["Plasticity," part I, OGIZ, Moscow-Leningrad, 1948; see AMR **6**, Rev. 464] is normally a function only of the invariants of strain, becomes also a function of the temperature. When the total strain remains small, the appropriate function for a perfectly elastic, linearly strain-hardening material is shown to include an extra term depending linearly on the temperature change. R. M. Haythornthwaite, USA

Failure, Mechanics of Solid State

(See also Revs. 415, 444)

456. **Grover, H. J., Gordon, S. A., and Jackson, L. R., Fatigue of metals and structures,** Washington, U.S. Government Printing Office, 1954, x + 394 pp. $2.50.

The objective of the book, "to supply information for designer to prevent and resist fatigue failures," is well and amply met. In the opening chapters, general aspects of fatigue failures are discussed, followed by an explanation of the presentation of fatigue data and reliability (statistical aspects) of fatigue test results. Chaps. 4 and 5 contain topics on fatigue damage and fatigue under combined stresses, respectively. The next five chapters (6 through 10) deal with various effects on fatigue properties of metals, such as stress concentration, surface effects, effects of size and shape, elevated temperatures, and others. There is omission of effects of hydrogen embrittlement on fatigue, and this variable gains considerable attention among the workers in the field of materials and among designers.

The remaining chapters deal with fatigue problems related to specific materials and machine and structural components. An impressive compilation of data on fatigue strength of various metals, presented in tabular form, closes the book. Each chapter is supplied with well-selected references. The photographic material is a helpful supplement to the written text. The book is reasonably exhaustive and well organized. An inclusion of a subject index, general list of references, and a list of symbols in common use, would greatly facilitate searching for a particular topic.

The book is strongly recommended as basic information on up-to-date data on fatigue; it is a "look first" item in dealing with fatigue problems in engineering problems.

R. M. Evan-Iwanowski, USA

457. **Clayton-Cave, J., Taylor, R. J., and Ineson, E., Reproducibility of Wöhler-type fatigue tests,** *J. Iron Steel Inst. Lond.* **180**, part 2, 161–169, June 1955.

Experiments designed to determine the variations in fatigue life obtained from (1) individual testing machines, (2) a battery of testing machines, and (3) similar machines in different laboratories, are discussed in this paper. The tests are planned and analyzed statistically.

Results indicate that fatigue data from a batch of machines are more variable than those provided by an individual machine. Tests conducted in more than one laboratory introduce even more variation. A study of fracture location revealed no particular difference between different machines.

Tests on a variety of specimens revealed no significant change in results if a common critical section is maintained.

Some precision of the experiment is lost due to the unexpected variability of the material. J. E. Stallmeyer, USA

458. **Eyers, J., Inspection, explosion and breakdown of boilers and pressure vessels,** *Instn. mech. Engrs. Proc.* **169**, 8, 181–188, 1955.

459. **Weibull, W., New methods for computing parameters of complete or truncated distributions,** *Flygtekn. Försöksanst. Medd. Rep.* no. 58, 1–21, 1955.

Two new types of distribution moments are introduced which may be used with advantage for computing the parameters of a large family of functions. The procedure is demonstrated on a particular distribution function which has been found by experience to fit various static and fatigue strength data with good fidelity. The methods are also applicable to truncated or censored distributions which may be required when dealing with distributions composed of more than one component or with fatigue tests stopped at some predetermined time before all the specimens have failed. Numerical examples are given.

From author's summary by H. T. Corten, USA

460. **Fisher, W. A. P., and Winkworth, W. J., Improvements in the fatigue strength of joints by the use of interference fits,** *Aero. Res. Counc. Lond. Rep. Mem.* no. 2874, 17 pp., May 1952, published 1955.

A study is made of the effect of interference fit in loaded holes on the fatigue strength of the associated part.

Fatigue-test results are given for aluminum-alloy flat bars with a single hole loaded by a pin in double shear. Two series of tests were made. In one series the pin was fitted directly in the hole with various degrees of interference fit up to 0.003 in. excess diam. The other series had a mild steel bush interposed with similar degrees of interference in the bar, but with a push fit between pin and bush. Both sets showed a great increase in fatigue strength for interference fits above a critical value.

The application of these results for raising the fatigue strength of aircraft structural joints is considered.

From authors' summary

461. **Jacobs, F. A., and Hartman, A., The effect of sheet thickness and overlap on the fatigue strength at repeated tension of redux bonded 75S-T clad simple lap joints,** *Nat. LuchtLab. Amsterdam Rap.* M.1969, 7 pp., 9 tables, 26 figs., Oct. 1954.

Static and fatigue tests were carried out on simple lap joints made from 0.8-, 1.2-, and 2.0-mm sheet with an overlap varying from 12.5 to 50 mm. The fatigue strength, if calculated as shear stress in the glue, decreases if the overlap increases; but, if calculated as tensile stress in the sheet, increases if the overlap increases. The joint factor hypothesis was not clearly confirmed by the results. From authors' summary

Material Test Techniques

(See also Revs. 451, 617)

462. **Pradzyński, A., Ultrasonic flaw detection and its use in aircraft industry** (in Polish), *Techn. Lotn.* **9**, 4, 93–98, July/Aug. 1954.

463. **Marriner, R. S., Performance tests on indentors for Rockwell hardness testing,** *Engineer, Lond.* **200**, 5189, 56–58, July 1955.

To establish a standard of hardness using the Rockwell principle, it is necessary to know to what extent hardness values are affected by the choice of indentor. Direct comparison of a few results from different indentors can be misleading, as the local variations of the test blocks used and variability of the testing

machine affect such comparisons. Details of a method of eliminating these sources of variability from the results are given and some additional sources of performance difference, such as the orientation of the crystallographic axes of the diamonds, are discussed. From author's summary

464. Flanders, D. F., Interpretation of ultrasonic tests through the use of statistical quality-control techniques, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54-A-226, 6 pp.

465. Hausseguy, L., and Martinod, H., A new nondestructive method for the measurement of superficial internal stresses (in French), *Rech. aéro.* no. 37, 43–50, Jan./Feb. 1954.

It has been found that the value of the Rockwell B hardness depends on the surface stresses in the specimen, the influence being small for compressive and appreciable for tensile stresses. Plotting the values of the hardness (according to Herz) as a function of the applied stress gives rise to a curve, consisting of two nearly straight lines which intersect at the point of zero surface stress. The abscissa of this point is a measure for the internal stress.

As the impressions of the ball are to be measured with an accuracy of about 10^{-5} mm, a special hardness tester was constructed and is described in the paper. It is suggested that the method might be useful for the study of the changes in surface hardness during fatigue. R. G. Boiten, Holland

466. Hartbower, C. E., Poisson effect in the Charpy test, *Proc. ASTM* **54,** 929–938, 1954.

A definite value of transition temperature may be determined by the Charpy impact test only through use of a clearly defined criterion to distinguish between ductile and brittle failure. One such criterion is based on maximum amount of lateral contraction at base of notch after rupture (e.g., 1%). This contraction, and accompanying lateral expansion on compression side of specimen, is referred to as Poisson effect.

It is shown that linear relationships exist in a useful range between lateral contraction, lateral expansion, and energy absorbed in fracturing specimen. Thus either of the latter may be substituted for lateral contraction as criterion for transition temperature. Since energy absorbed is read directly on a dial in the Charpy impact test, this provides the best criterion in this case. On the other hand, extending results to slow bend tests of notched specimens, lateral expansion is found to be easiest measurement. Linear relationships make comparison of the two tests a simple matter.

Extent of linear relationships and effects of changes in metallurgical variables and changes in specimen shape are discussed and illustrated by graphs. C. W. Richards, USA

Mechanical Properties of Specific Materials

(See Revs. 456, 461, 473, 584, 594)

Mechanics of Forming and Cutting

467. Denst, A., and Ross, H. V., How to machine uranium, *Amer. Machinist* **99,** 16, 95–97, Aug. 1955.

468. Sata, T., and Mizuno, M., Friction process on cutting tool and cutting mechanism, *J. sci. Res. Inst. Tokyo* **49,** 1391–1395, 163–174, June 1955.

Paper presents an interesting discussion of the basic reasons why friction in metal cutting is different from ordinary rubbing processes, views that are now quite widely accepted. Some of the authors' conclusions regarding two types of continuous chips are not substantiated by enough data. The conclusions reached for the relationship between shear and rake angles agree with the data plotted, but not with a considerable amount of other experimental data in existence. E. Loewen, USA

469. Green, A. P., On unsymmetrical extrusion in plane strain, *J. Mech. Phys. Solids* **3,** 3, 189–196, Apr. 1955.

Author presents modification to Hill's solution [*J. Iron Steel Inst.* **158,** p. 177, 1948] for the slip line field and extrusion pressure where extrusion is through a square die at the bottom of a container but offset from its center. Calculations are for smooth and rough-walled container. Solutions are also proposed for extrusion through a side aperture. A plastic-rigid nonhardening material is assumed. Plasticine experiments are described which confirm the side extrusion solution closely and the end extrusion reasonably. P. Whitton, Australia

470. Shield, R. T., The plastic indentation of a layer by a flat punch, *Quart. appl. Math.* **13,** 1, 27–46, Apr. 1955.

Upper and lower bounds for the average pressure in the indentation by a flat, smooth punch of the plane surface of a layer of elastic perfectly plastic material resting on a rough rigid base are obtained by the application of the limit-design theorems. The material of the layer is assumed to obey Tresca's yield criterion of constant maximum shearing stress during plastic deformation. The square punch problem is considered in detail for layers whose thickness is greater than one fourteenth of the width of the punch. For thinner layers, reasonably close upper and lower bounds for the average pressure over the square punch are obtained as functions of the relative thickness of the layer. The circular punch is considered briefly, and the bounds obtained determine the indentation force with sufficient accuracy for layers which are not too thick compared with the width of the punch. From author's summary by W. E. Cooper, USA

471. Halliday, J. S., Surface examination by reflection electron microscopy, *Instn. mech. Engrs.*, 7 pp., 4 plates, 1955.

472. Wilkins, W. B., Molding reinforced plastics with low-cost cores, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54-A-198, 3 pp.

473. Kellermann, R., and Alsen, K., Measurement of force and power requirement with strain gages in cold pressing (in German), *Werkstattstech. Maschinenb.* **44,** 8, 363–369, Aug. 1954.

To obtain above quantities the press die is set in a calibrated steel cylinder on which several strain gages are fastened. The strain gages are connected with a bridge and oscilloscope. The pattern on the oscilloscope gives a force-time distribution curve. To obtain a time-distance curve, an indicator drum, driven by a synchronous motor, is used. Out of the two curves a force-distance curve is developed. This gives force distribution and peak force, while the area under the curve gives work done in cold-pressing operation.

In the experiment described, bolt heads were formed. The method is particularly suitable for determination of short-lasting elastic and plastic deformations. It can give an accurate indication of peak force and force distribution which is unobtainable by means of hydraulic gages, due to inertia delays. However, calorimetric determination of work required for cold pressing is superior to the strain-gage method, as it is relatively simple, inexpensive, and, therefore, lends itself to numerous checks.

B. Hawrylyshyn, Canada

474. **Luboiński, J., and Szczepiński, W., Zinc-alloy blanking** dies (in Polish), *Techn. Lotn.* **9**, 3, 87–88, May/June 1954.

Hydraulics; Cavitation; Transport

(See also Revs. 487, 493, 535, 618, 620)

475. **Analyses of a complex tank system (a symposium of three papers): Balint, C. E., Development of a design formula; Flower, W. R., The mathematical theory of surge tanks; Frueh, F., Hydraulic model of double surge tank system,** *J. Instn. Engrs. Austral.* **27**, 6, 155–166, June 1955.

Author of the first article presents a clear and analytical review of the different methods adopted to examine the "stability of oscillations" in surge tanks. He then illustrates, by an example, the calculations for one of them.

The second article exposes an exhaustive mathematical solution for studying a system which consists of one or two surge tanks. Adopting a linear relationship to govern the equations, two methods of calculation are employed to derive the equations for the condition of stability. However, graphical methods yield results of greater accuracy. In one of reviewer's latest publications ["Nouveaux Compléments d'Hydraulique"] a mathematical solution to the problem is proposed and the results obtained by this solution are described.

The third and final article describes the requisite components for the construction of a scale model to verify the oscillations and the "condition of stability" in surge tanks.

This important series of articles presents a significant contribution to the study of oscillations in surge tanks and their requisite conditions for "stability." L. Escande, France

476. **Binnie, A. M., Davies, P. O. A. L., and Orkney, J. C., Experiments on the flow of water from a reservoir through an open horizontal channel. I. The production of a uniform** stream, *Proc. roy. Soc. Lond.* (*A*) **230**, 1181, 225–236, June 1955.

Authors describe a series of experiments in open channel flow to determine the conditions for which the stream is uniform in depth and velocity. At no time, however, do the authors establish the limits for these conditions.

Two channels were used, the first having a 6-in. width, 3-in. nominal stream depth, and 41-in. length, the second being 14 in. wide, 7-in. nominal depth, and 8 ft long. The entrance conditions to both channels were trumpet-shaped rectangular orifices. The first author had shown previously that this form of entrance should establish a uniform stream more conveniently than other devices in use.

The Froude number for the flow ranged well above and below unity. Nonuniformity in depth due to energy dissipation was apparently not serious except when a hydraulic jump would form.

Considerable attention is given to ripples and small waves disturbing the surface. The small waves are found to be in essential agreement with the theory of wave formation due to reduction in flow momentum. In tranquil flow, these waves have small or negligible amplitude with F less than 0.5. Reviewer believes the results concerning these waves are the major contribution of this paper. H. G. Farmer, Jr., USA

477. **Binnie, A. M., and Orkney, J. C., Experiments on the flow of water from a reservoir through an open horizontal channel. II. The formation of hydraulic jumps,** *Proc. roy. Soc. Lond.* (*A*) **230**, 1181, 237–246, June 1955.

The stream, on which the experiments were carried out, was produced by leading water from a reservoir through a rectangular contraction into an open channel that was slightly inclined downward. By means of a hinged planing plate resting on the surface, single waves and wave trains fixed in space were formed ahead of the plate, and the required loads on the plate were measured. A more systematic study of smooth and broken undular jumps was made, with a weir at the channel outlet providing the necessary obstruction. The boundary between these two types of jump was at $F_1 = 1.26$, F_1 being the Froude number of the approaching stream. The second type decayed into the wholly turbulent jump at about $F_1 = 1.75$. Little difference was found between the heights of the leading wave in the smooth undular jumps and the theoretical heights of a solitary wave formed at the same Froude number, and Rayleigh's classical theory (1914) gave a fair approximation of the mean depth in the undular trains of waves.

From authors' summary by H. G. Farmer, Jr., USA

478. **Rothfus, R. R., Monrad, C. C., Sikchi, K. G., and Heideger, W. J., Isothermal skin friction in flow through annular sections,** *Indust. Engng. Chem.* **47**, 5, 913–918, May 1955.

The data obtained for Reynolds number range $900 < N_{Re_2} < 45{,}000$ by direct measurement of drag forces on the tubes of concentric annuli with isothermal vertical downward flow of water are analyzed. The following aspects are indicated:

(1) At distances greater than 250 equivalent diameters from the entrance, the friction factor j_f approaches the asymptotic value to within only a few per cent. The effect of the particular entrance condition on j_f throughout the Reynolds number range is illustrated.

(2) Two apparently stable values of the entrance effect as given by two values of j_f near the entrance region are reported. This phenomenon is attributed to the two "stabilized" turbulence levels induced by the entrance of the conduit.

(3) The assumption that the radius at which the mean level fluid velocity attains its maximum value can be evaluated with laminar viscous flow in the annuli is verified for $N_{Re_2} > 900$.

The effect of transition is also briefly discussed. A procedure of determining friction for flows with $N_{Re_2} > 6000$ (asymptotic region) is proposed. S.-I. Cheng, USA

479. **Lebedev, I. V., Local scour past horizontal apron** (in Russian), *Gidrotekh. Stroit.* **23**, 8, 40–43, 1954.

This is a destructive discussion on the article by M. S. Vyzgo, [AMR **8**, Rev. 1711]. Further discussion on same subject: Beliashevskiĭ, N. N. ["Methods of control of tailwater past spillways," title source, **24**, 3, 40–42, 1955]; Frolikova, E. Ia. ["Variable distribution and pulsation of kinetic energy beyond a hydraulic jump," ibid., **24**, 4, 42–44, 1955, see following review]. S. Kolupaila, USA

480. **Frolikova, E. I., Variable distribution and pulsation of kinetic energy beyond a hydraulic jump** (in Russian), *Gidrotekh. Stroit.* **24**, 4, 42–44, 1955.

This continues the discussion on an article by Vyzgo [AMR **8**, Rev. 1711], particularly concerning a length of a downstream apron. Correct evaluation of a conjugated depth beyond a hydraulic jump depends on value of a kinetic energy factor in Bernoulli equation. This factor, sometimes neglected, is actually many times larger than unity. Several empirical formulas were offered for computation of this factor, based on various assumptions. Six of them are compared in the article, among them one American, by Bakhmeteff and Matzke. Results are deplorable. Insufficiency of instruments for registration of pressure and its pulsation makes impossible a more correct analysis of the phenomenon. S. Kolupaila, USA

481. Hydraulic installations, *Escher Wyss News* **25/26,** pp. 1–172, 1952/1953.

This continuation of record of achievement of Escher Wyss, Ltd., in the hydraulic turbine field during the past ten years completes the record started in the article "A century of turbines" in *Escher Wyss News*, **15/16.** Work covers research, design, construction, and operation of hydraulic turbines and accessories. Each section concerns a particular subject and is presented by a different author. Work contains descriptions of outstanding installations, making liberal use of beautiful illustrations, photographs, and sectional drawings; machine shop developments, including copying-type milling machines; specific turbines, such as high-head Francis and propeller, Kaplan, impulse, and tubular; model tests; regulating systems; turbine auxiliary; operating problems; and pump storage plants.

Reviewer notes the principal contributions to be: (a) testing of turbine models including the complete associated flow system to model scale; (b) development of pump storage plants to 85,000 hp and 400 m of head; (c) development of efficient tubular turbines in the smaller sizes, (d) development and use of equipment for profile machining procedures in manufacturer propeller blades; (e) wear tests, including special equipment to study sand erosion; (f) development of high-head Francis turbines to 63,000 hp and 455 m of head; (g) development of Kaplan turbines for 60 to 80 m of head. This is required reading for anyone interested in hydraulic turbines and associated equipment.

R. G. Folsom, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 498, 505, 513, 536, 538, 539, 540, 544, 590, 601, 607, 608, 610, 619)

482. Oprecht, U., Investigation of hydrodynamic coupling (in German), *Motortech. Z.* **16,** 10, 285–290, Oct. 1955.

483. Lew, H. G., On the stability of the axial symmetric laminar jet, *Quart. appl. Math.* **13,** 3, 310–314, Oct. 1955.

484. Kapryan, W. J., and Boyd, G. M., Jr., Hydrodynamic pressure distributions obtained during a planing investigation of five related prismatic surfaces, *NACA TN* 3477, 82 pp., Sept. 1955.

Pressure-distribution surveys have been made for five related prismatic surfaces, having angles of dead rise of 0°, 20° with and without horizontal chine flare, and 40° with and without horizontal chine flare, as part of general research on planing surfaces. Pressure distributions, which gave integrated lifts to well within 10% of the applied load, were obtained during pure planing and are presented for wetted-length beam ratios ranging from approximately 0.5 to 5, trims from 4° to 30°, and beam loadings from approximately 2.8 to 38.

The results substantiate the use of the normal-load coefficient as the key parameter in predicting flat-plate centerline pressures. The results further show that flat-plate pressure distributions can be adequately predicted from existing theories. The reduction in pressure accompanying an increase in angle of dead rise is about as would be expected on the basis of previous force measurements. The addition of horizontal chine flare increases the pressure near the chines and extends the region of positive pressures further forward of the stagnation point in the vicinity of the chines. Existing theories are in poor agreement with the experimental pressure distributions obtained for surfaces having dead rise. The lift and centers of pressure are in good agreement with recent experimental and theoretical NACA research on planing surfaces. From authors' summary

485. Harder, K. C., and Rennemann, C., Jr., On boattail bodies of revolution having minimum wave drag, *NACA TN* 3478, 28 pp., Aug. 1955.

The problem of determining the shape of slender boattail bodies of revolution for minimum wave drag has been reexamined. It was found that minimum solutions for Ward's slender-body drag equation can exist only for the restricted class of bodies for which the rate of change of cross-sectional area at the base is zero. In order to eliminate this restriction, certain higher-order terms must be retained in the drag equation and isoperimetric relations. The minimum problem for the isoperimetric conditions of given length, volume, and base area is treated as an example. According to Ward's drag equation, the resulting body shapes have slightly less drag than those determined by previous investigators. From authors' summary

486. Okabe, J., Approximate calculations of laminar jets, *Rep. Res. Inst. appl. Mech.* **4,** 13, 23–27, July 1955.

487. Yih, C.-S., Stability of parallel laminar flow with a free surface, *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., June 1955, 623–628.

Author performs two-dimensional stability investigation based on the Navier-Stokes and the continuity equations. By the usual linearization process the Sommerfeld-Orr equation is obtained. This is solved by a series expansion in ascending powers of the Reynolds number, R, since unstable condition is expected at rather low values of R. Numerical details are given for vertical flow, and it is shown that: (1) if $R < 1.5$, the flow is stable independently of the wave number (2π *depth/wave length*); (2) increasing the viscosity has a stabilizing effect; (3) the free surface has a destabilizing effect; and (4) for neutral disturbances, the celerity of propagation increases with wave length.

Reviewer considers paper of considerable academic interest.

V. G. Szebehely, USA

488. Lin, T. C., Ducts for accelerated flow, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., June 1955, 629–635.

Design procedure is given for two-dimensional contracting ducts for incompressible inviscid flows. The contraction consists of three parts: the inlet and outlet which are isobaric lines, and a straight central portion. The corresponding domain in the hodograph plane is fan-shaped; the isobars are represented by circular arcs around the origin, and the central portion by straight lines through the origin. By triple comformal transformation, the parametric representation of the desired shape in the physical plane is obtained. The total length of the contraction is minimized and the corresponding channel angle for the central portion and the parameters governing the duct shape are computed. The design method gives essentially uniform flow at both ends and eliminates pressure discontinuities or adverse pressure gradients. Details are given for contraction ratios 3 and 10. Extension of the method for Y-shaped channels is indicated.

V. G. Szebehely, USA

489. Kanwal, R. P., Rotatory and longitudinal oscillations of axi-symmetric bodies in a viscous fluid, *Quart. J. Mech. appl. Math.* **8,** part 2, 146–163, June 1955.

Stokes' stream function is used to find fluid motion induced by harmonic oscillation of sphere, circular cylinder, prolate and oblate spheroid, and circular disk. Modes considered are rotation about and translation along axis of rotational symmetry. Slow motion is considered, in which nonlinear inertia terms are neglected. Case of longitudinal oscillation of circular cylinder is omitted, perhaps because of close similarity to rotatory problem.

However, both are of interest as examples of slow motions that happen to satisfy full Navier-Stokes equations.

M. D. Van Dyke, USA

490. **Van Der Bliek, J. A., The zero-lift drag of full and half-models of a body of revolution at $M = 1.6$,** *Nat. aero. Establ. Canad.* LR 139, 15 pp. + xi figs., May 1955.

The zero-lift drag of a body of revolution was measured in the 10 × 10-in. and the 30 × 16-in. wind tunnels at $M \approx 1.6$ and for Reynolds numbers, based on body length, from 2.8 to 6 million. Both a full model and two half-models, the latter of different sizes and with different boundary-layer shim thicknesses, were investigated.

It was found that the drag coefficients of half-models, when displaced 0.25 in. from the tunnel wall, were approximately the same, irrespective of the model size, as for the full model with fully turbulent boundary layer, obtained by artificial transition near the nose.

Five different techniques of boundary-layer flow visualization were utilized on the full body. A mixture of French chalk and kerosene was found to be the most suitable method.

From author's summary

491. **Jain, M. K., Boundary layer effects in non-Newtonian fluids,** *ZAMM* **35,** 1/2, 12–16, Jan./Feb. 1955.

The motion of such incompressible fluid, particularly past a circular cylinder and past a sphere, is computed. A field of external forces is introduced "to make the equations integrable."

It is not explained why it is not easier to start with any solution subject merely to the boundary conditions and free of divergence and to compute the associated force field necessary to keep the flow steady. It is shown that a number of well-known relations are consistent with the results. M. M. Munk, USA

492. **Mitchell, A. R., and Murray, J. D., Two-dimensional flow with constant shear past cylinders with various cross sections,** *ZAMP* **6,** 3, 223–234, 1955.

Method consists of subtracting from ψ the stream function for constant shear flow. The resulting stream function satisfies the Laplace equation with known boundary values on the cylinder cross section. This boundary-value problem is solved by separation in natural coordinates for elliptical and parabolical cylinders. The location of the stagnation points is discussed.

L. J. F. Broer, Holland

493. **Magyar, F., Stream functions for free outflows from a swirl chamber** (in German), *Öst. Ing.-Arch.* **9,** 1, 24–30, 1955.

Author claims to give the stream function for the meridian component of flow in case of axially symmetric free outflow from a swirl chamber, similar to the stator of a Reiffenstein impulse turbine, in which a rotating annular jet emerges from one side of a spiral inlet casing and acts on an appropriately designed impulse runner. Rotational velocity is assumed to follow law of constant angular momentum.

While author's function satisfies the boundary conditions assumed, he has not verified that it satisfies equation for Stokes' stream function, and, according to reviewer's examination, it does not. It must therefore be regarded as only an approximation to the true solution. It may, however, be adequate for practical purposes.

A second problem studied is outflow from swirl chamber into coaxial cylindrical tube. Proposed stream function is not given in explicit form, but is probably also only an approximation.

A. Burn, Australia

Compressible Flow, Gas Dynamics

(See also Revs. 513, 515, 520, 521, 522, 532, 534, 585, 598, 599)

494. **Roumieu, M. C., On the structure of the oblique shock joining two uniform streams** (in French), *C. R. Acad. Sci. Paris* **241,** 4, 356–357, July 1955.

Assuming that the velocity components and all the thermodynamic variables depend on only the coordinate x, author obtains from the usual equations of motion of a two-dimensional steady viscous and heat-conducting fluid a set of simple ordinary differential equations, which can be used to describe the structure of an oblique shock (perpendicular to the x-direction, of course) joining two uniform streams. The result is an extension of the one due to Gilbarg and Paolucci concerning the normal shock [AMR **7,** Rev. 2531]. S. F. Shen, USA

495. **Woods, L. C., The design of two-dimensional aerofoils with mixed boundary conditions,** *Quart. appl. Math.* **13,** 2, 139–146, July 1955.

Author undertakes to develop a method of designing symmetrical airfoils for which the shape of the nose and trailing edge is specified and the pressure distribution over the intermediate portion is given. Attention is restricted to airfoils at zero incidence in subsonic compressible flow of a "Karman-Tsien tangent gas." The essential problem is, of course, to determine the required airfoil shape in incompressible flow. This calculation is facilitated by a well-chosen conformal transformation. It is indicated how "roof top" airfoils can be designed relatively quickly with the proposed method. Of more general importance, however, the method gives the designer direct control of the fore and aft portion of his airfoil. A. J. Eggers, Jr., USA

496. **Germain, P., Maximum theorems and reflections of simple waves,** *NACA TN* 3299, 22 pp., June 1955.

Author derives expressions in terms of Fourier transforms for the stream function of flows resulting from reflections of a simple centered wave from (a) a straight wall and (b) a free streamline. It is shown that (a) gives a physical interpretation of the maximum theorem of Bers regarding the bounds of the solution of the related Cauchy problem and gives a more precise result. The qualitative properties of (b) establish a relation between the occurrence of a limiting line and the range of validity of a maximum theorem for the Tricomi problem previously derived by the author. J. S. Holdhusen, USA

497. **Eggers, A. J., Jr., Savin, R. C., and Syvertson, C. A., The generalized shock-expansion method and its application to bodies travelling at high supersonic air speeds,** *J. aero. Sci.* 22, 4, 231–238, 248, Apr. 1955.

It is demonstrated that the shock-expansion method can be generalized to treat a large class of hypersonic flows, only one of which is flow about airfoils. This generalized method predicts the whole flow field, including shock-wave curvatures and resulting vorticity, provided certain conditions are met. It is shown that this is the case in three-dimensional as well as two-dimensional hypersonic flows. When they are met, surface streamlines may be taken as geodesics, which, in turn, may be related to the geometry of the surface. The validity of the generalized shock-expansion method for three-dimensional hypersonic flows is checked by comparing predictions of theory with experiment for the surface pressures and bow shock waves of bodies of revolution. At the lower angles of attack, theory and experiment approach agreement when the hypersonic similarity parameter exceeds unity. At the larger angles of attack, theory tends to

break down, as would be expected, on the leeward sides of the bodies. As a final point, authors raise the question whether two-dimensionality of inviscid hypersonic flows has any counterpart in hypersonic boundary-layer flows. The question is answered in the affirmative, and results of experiment are employed to provide a partial check of this conclusion.

From authors' summary by T. Gullstrand, Sweden

498. Barua, S. N., A source in a rotating fluid, *Quart. J. Mech. appl. Math.* **8,** part I, 22–29, Mar. 1955.

Paper deals with a problem described in the author's summary as follows: "The flow due to a source placed on the axis of rotation in an otherwise uniformly rotating fluid is discussed. In the ultimate state the irrotational flow due to the source is confined to the region inside a cylindrical discontinuity surface which has a bulge in the neighborhood of the source, the surface being symmetrical about the axis of rotation."

Some numerical calculations on the shape of the bulge near the source are presented. No immediate physical applications are indicated. M. J. Thompson, USA

499. Ericsson, U., Explosive shock travel times at different ambient densities, *Appl. sci. Res.* (*A*) **5,** 4, 309–320, 1955.

Author has studied the shock front velocity generated by detonating spherical TNT charges in air at densities between 0.047 and 1.33 kg/m³. Drum camera records were obtained by photographing the self-luminous shock wave. A comparison is made with other experiments and the data are fitted by a second-degree polynomial. Approximate agreement with relations derived by dimensional analysis is indicated over the density range when density-dependent coefficients are used in the polynomial.

H. M. Spivack, USA

500. Griffith, W. C., and Bleakney, W., Shock waves in gases, *Amer. J. Phys.* **22,** 9, 597–612, Dec. 1954.

A very readable and informative account of some aspects of shock tube research. Reviewer would like to recommend it, especially to those who are not yet acquainted with this field of research. I. I. Glass, Canada

501. D'yakov, S. P., Interaction of shock waves with tangential and weak discontinuities (in Russian), *Doklady. Akad. Nauk SSSR* (*N.S.*) **99,** 921–923, 1954.

Author classifies all important cases of interaction of shock waves with tangential discontinuities (i.e., vortex sheets and free streamlines), of one tangential discontinuity with another, and of weak waves with shock waves and tangential discontinuities, respectively. Only regions of plane steady uniform flow are considered. Maurice Holt, England

502. Dubinskii, M. G., On rotating gas flows (in Russian) *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 8, 75–78, 1954.

In a swirling axisymmetric flow with nonzero velocity components c_z = const parallel to the axis of symmetry of a system of cylindrical coordinates r, z, and $c_u = \Omega r + \Delta(r)$ normal to planes through the z-axis, where Ω is constant, the pressure $p(r)$, density $\rho(r)$, and specific entropy $s(r)$ are subject to only two conditions $dp/dr = \rho c_u^2/r$ and the adiabatic law. In such a flow with $\Delta(r) = 0$, the pressure $p_2 = p(R)$ at the surface of a tube of radius R and $p_0 = p(0)$ on its axis can be expressed in terms of the rate of flow across any section z = const of mass, momentum, angular momentum, kinetic energy, and E_u the kinetic energy due to swirl. If to obtain a third condition for p, ρ, and s the function $p(r)$ is required to be such as to produce maximal rate of entropy flow with constant E_u, an isoperimetric problem results whose solution implies $(p - p_0)/(\rho - \rho_0)$ = const. This relation can be satisfied in particular by the radial temperature distribution $T(r)$ = const. Finally, of all the swirling flows with given Ω and density distribution $\rho(r)$, the choice $\Delta(r) = 0$ yields minimum E_u. J. H. Giese, USA

Wave Motion in Fluids

(See also Rev. 496)

503. Hunt, J. N., Gravity waves in flowing water, *Proc. roy. Soc. Lond.* (*A*) **231,** 1187, 496–504, Sept. 1955.

Effect of nonuniform steady current on propagation and shape of two-dimensional waves is studied.

First part deals with linear theory of disturbances on a steady current varying as the one-seventh power of the relative height above the bed. Disturbance is characterized by a stream function, simple harmonic in time and horizontal ordinate.

Author derives a differential equation from equations of motion and usual boundary conditions, i.e., zero vertical velocity at bottom and constant pressure at surface. Further simplification, long wave, and small amplitude, i.e., condition of Stokes, results in a hypergeometric equation.

The solution provides the velocity of propagation. For finite wave length, a solution is obtained by the method of variation of parameters. Link between solution of Lighthill [AMR **7,** Rev. 3143, appendix] and nearly stationary wave pattern is given, too.

In the second part, a nonlinear treatment for appreciable wave amplitude is given as an interesting extension of Keulegan and Patterson [*J. Res. nat. Bur. Stands.* **24,** 47–101, Jan. 1940] to the same degree of accuracy. Steady current distribution and disturbance stream function are approximated by power series.

Velocity and shape of the waves depend on the nonuniformity of the steady current. Author shows, to the mentioned degree of accuracy, that only the value of this current at the free surface and its first derivative are the determining quantities.

The ultimate differential equation is solved for the solitary and the conoidal wave. The latter is studied for great wave length to be compared with direct solution for solitary wave.

H. J. Schoemaker, Holland

504. Havelock, T., Waves due to a floating sphere making periodic heaving oscillations, *Proc. roy. Soc. Lond.* (*A*) **231,** 1184, 1–7, July 1955.

Author considers a sphere half-immersed and making small vertical oscillations in nonviscous liquid with a free surface otherwise undisturbed. The problem has been studied in general form by John [AMR **4,** Rev. 2563]. The two-dimensional problem related to heaving motion of a half circular cylinder has been studied by Ursell [AMR **3,** Rev. 1727; **7,** Rev. 1030]. Grim [Jahrbuch Schiffbautech. Gesellsch. **47,** p. 277, 1953] has studied, both theoretically and experimentally, the heaving motion of cylinders with various forms of cross section, more especially with a view to application to ship problems in estimating virtual inertia and damping coefficient. In the two-dimensional case, the virtual inertia coefficient approaches an infinite value as the frequency becomes small; this is no doubt connected with the fact that the condition at the free-water surface then approximates to that for a rigid boundary, and the two-dimensional potential problem with that boundary condition is indeterminate. This does not arise for three-dimensional motion; the general case approximates to determinate potential problems in the two limits as the frequency approaches zero or infinity. The point of special interest is the variation of the virtual inertia coefficient with frequency between these limiting values. A solid of ship

form would come between the two extremes of an infinite cylinder and a sphere.

Reviewer thinks that the problem is of great interest to naval architects and that it brings out an important result.

S. D. Nigam, India

505. **Morgan, G. W., and Ferrante, W. R., Wave propagation in elastic tubes filled with streaming liquid,** *J. acoust. Soc. Amer.* **27,** 4, 715–725, July 1955.

In the case studied, the liquid is incompressible and of small or vanishing viscosity. The tube wall is thin, but its inertia and Poisson ratio are considered. The steady stream is laminar, with parabolic profile. The wave motion has a wave length long compared to the tube radius, and a particle velocity small compared to that of the steady stream. Phase velocity and damping are computed. The mean stream velocity enters the former additively, except for small terms involving viscosity, wall inertia, Poisson ratio. The principal effect of wall inertia is nondispersive. Damping is less for downstream than upstream propagation; wall inertia reduces damping in either case. Disagreement with experiments by Müller [*Helv. Physiol. et Pharmacol. Acta,* 8, 228, 1950] is noted but not explained.

P. Rudnick, USA

506. **Teofilato, S., A new laboratory device for the study of wave motion** (in Italian), *G. Gen. civ.* **93,** 5, 310–315, May 1955.

This is a description of a wave machine built for an experimental channel, 6 m long and 0.6 m wide, in the Hydraulics Laboratory of the University of Rome. The device consists of a hinged-leaf gate set in alternate motion through an epicyclic grain of gears driven by a direct-current electric motor. Wave profiles are recorded through an electronic apparatus with fixed and moving point gages. They show deviations less than 6% if compared with trochoidal theory profiles. These results should be appreciated if one considers that measured wave lengths could attain half the channel length. A. Ghetti, Italy

Turbulence, Boundary Layer, etc.

(See also Revs. 548, 570, 572)

507. **Schubauer, G. B., and Klebanoff, P. S., Contributions on the mechanics of boundary-layer transition,** *NACA TN* 3489, 31 pp., Sept. 1955.

Report presents results of careful experimental investigation of mechanism of transition from laminar to turbulent flow in boundary layers. Cases investigated are natural transition with various amounts of free-stream turbulence, transition induced by trip wire, development of turbulence behind three-dimensional roughness element, and, finally, turbulence caused by short-duration electric spark in laminar boundary layer. Measurements are carried out on flat plate model in the National Bureau of Standards low-speed wind tunnel at speeds generally below 100 fps. Most of significant information is obtained from oscillograms of one or two hot-wire signals.

In all cases, experimental evidence can be reconciled with following picture of transition: Perturbations in laminar flow cause local breakdowns which develop into "spots" of turbulence. These spots move downstream with flow, at the same time growing in size, merging together and finally covering entire span all the time. Hot-wire recording taken in transition region shows successive turbulent "patches" with laminar flow between them. Flow following passage of turbulent "spot" or "patch" is found to be laminar and, in fact, to exhibit a "calming effect" which, for a while, prevents the formation of new disturbance; however, this calming effect does not prevent the leading edge of one spot from overtaking the trailing edge of another. Observations regarding shape, growth, and interaction of spots are presented. Natural transition as well as effect of roughness elements are compared to, and interpreted in terms of, the "single spot" obtained by short-duration spark.

Authors point out that the concept of transition from laminar to turbulent state actually consists of two parts: (1) initial breakdown of laminary flow due to a perturbation, and (2) spreading of turbulence into surrounding laminar region.

Report is a remarkable step toward the ultimate understanding of transition and is indispensable for everyone in the field.

R. J. Hakkinen, USA

508. **Brinich, P. F., A study of boundary-layer transition and surface temperature distributions at Mach 3.12,** *NACA TN* 3509, 30 pp., July 1955.

Surface temperature distributions on a hollow cylinder aligned with the airstream were studied in a Mach 3.12 wind tunnel at Reynolds numbers per inch from 1×10^5 to 7×10^5. Transition with and without single roughness elements was observed from the surface temperature distributions and from high-speed schlieren motion pictures.

Comparison of the surface temperature distributions obtained on the present model with those obtained in earlier cylinder tests indicates that, as the leading edge was made sharper, the temperature rise at the transition point became more abrupt; also, the temperature distribution became more similar to that observed on a cone under the same test conditions. Sharpening the leading edge also decreased the transition Reynolds number.

When a single roughness element was located in the laminar boundary layer, the surface temperature distribution was changed only slightly at the element, but the transition point was shifted upstream somewhat. When the roughness element was placed in the transitional or turbulent boundary layer, large perturbations in the temperature distribution resulted, with no change in transition Reynolds number.

From author's summary

509. **Tsuji, H., Experimental studies on the characteristics of isotropic turbulence behind two grids,** *J. Phys. Soc. Japan* **10,** 7, 578–586, July 1955.

In order to study the characteristics of isotropic turbulence produced under various initial conditions and at high Reynolds numbers, hot-wire measurements were made to determine the decay and the g-correlation of turbulence behind two grids, the upstream grid having a larger mesh length than the downstream one, in the 1.5-meter wind tunnel at the Institute of Science and Technology.

The linear decay law, $\overline{u^2} \sim x^{-1}$, does not hold in the presence of a large-scale slowly decaying turbulence produced by the first grid ahead of the second grid. On the other hand, Lin's decay law, $\overline{u^2} \sim [x^{-1} + \text{const}]$, which is supposed to be valid for the turbulence either behind a single grid or with superposed disturbances of low frequencies, is confirmed unless the large-scale turbulence produced by the first grid is overwhelmingly predominant, though the deviation from the self-preservation of correlation at large value of r is marked. The constant term in Lin's decay law, which expresses the deviation from the complete similarity, is negative for the single grid, but is positive in the presence of a superposed, large-scale turbulence.

From author's summary

510. **Levy, S., Heat conducting bodies in boundary-layer flow,** *J. aero. Sci.* **22,** 6, 440–441, June 1955.

Note in Readers' Forum.

511. Michael, D. H., A two-dimensional magnetic boundary layer problem, *Mathematika* **1,** 131–142, 1954.

In this paper, two-dimensional hydromagnetic problems are considered of which the following is typical. An infinite cylinder which is a perfect electrical conductor moves through a fluid of finite electrical conductivity σ and kinematic viscosity ν and encounters a magnetic field distribution which is initially normal to the axis of the cylinder; and the problem concerns the manner of the redistribution of the magnetic field which takes place. If the magnetic diffusivity λ ($= 1/4\pi\sigma\mu$ where μ denotes the magnetic permeability) is large compared to ν, then what happens is effectively the formation of a magnetic boundary layer around the cylinder. The nature of a resulting boundary layer is studied. A theorem of general interest which is established is that, under the circumstances considered, the magnetic flux per unit length which crosses the path of the cylinder remains constant throughout the motion. S. Chandrasekhar, USA

512. Carrier, G. F., Boundary layer problems in applied mathematics, *Comm. pure appl. Math.* **7,** 1, 11–17, 1954.

Lighthill's technique for rendering approximate solutions of nonlinear equations of physics [AMR **3,** Rev. 1829] and Carrier's boundary-layer methods of analysis [AMR **7,** Rev. 2915] are compared. Examples of the treatment of certain ordinary differential equations are given, showing the particular advantages of the two methods. F. N. Frenkiel, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 369, 443, 484, 495, 497, 529, 530, 534, 541, 542, 546, 609)

513. Duke, N., and Lanchbery, E., Sound barrier, the story of high-speed flight, New York, Philosophical Library, Inc., 1955, xi + 129 pp. $4.75.

This book is an excellent summary of the step-by-step development of high-speed aircraft and should be of extreme interest to those scientists and engineers, working outside of the aeronautical field, who wish to obtain a comprehensive picture of the problems confronting the design engineers in their attempt to achieve higher and higher speeds. The discussion is divided into such logical components as the airframe, the power plant, and the pilot's problem of maintaining control while being kept alive in a mechanically created environment. In conclusion, the authors forecast what developments may be expected in the future.

Reviewer disagrees with the authors' opinion that the book would be comprehensible to the nontechnical reader. Initially, an effort is made to introduce the reader to technical terms associated with aeronautics; however, as the story unfolds, it appears as though the authors, quite naturally, assume that their intended audience have somehow acquired a technical vocabulary and are capable of understanding the narration.

C. K. Longacre, USA

514. Diederich, F. W., and Zlotnick, M., Calculated spanwise lift distributions and aerodynamic influence coefficients for swept wings in subsonic flow, *NACA TN* 3476, 173 pp., Oct. 1955.

Spanwise lift distributions have been calculated for 61 swept wings with various aspect ratios and taper ratios and with a variety of angle-of-attack or twist distributions, including flap and aileron deflections, by means of the Weissinger method with eight control points on the semi-span. Also calculated for these planforms were aerodynamic influence coefficients which pertain to a certain definite set of stations along the span. The information presented can thus be used both in the analysis of untwisted wings or wings with known twist distributions and in aeroelastic calculations involving initially unknown twist distributions.

This paper supplements and is intended to be used in conjunction with *NACA TN* 3014 [AMR **7,** Rev. 1565], where the same type of information, calculated in the same way, is presented for 19 unswept wings. From authors' summary

515. McFadden, N. M., Rathert, G. A., Jr., and Bray, R. S., The effectiveness of wing vortex generators in improving the maneuvering characteristics of a swept-wing airplane at transonic speeds, *NACA TN* 3523, 43 pp., Sept. 1955.

Several modifications intended to alleviate the effects of shock-induced flow separation have been flight tested at transonic speeds and high altitudes on a swept-wing fighter airplane.

The effects of the modifications on the pitch-up and wing-dropping problems, the buffet boundary, aileron effectiveness, and airplane drag were investigated. Vortex generators were found to be effective in both the wing-dropping and pitch-up problems. The rapid increase in aileron stick force and angle required to hold the wings level above a Mach number of 0.92 was generally reduced and practically eliminated for 1g flight with an arrangement of vortex generators at 35% chord. The airplane normal-force coefficient at which a loss in lift on the outer portion of the wing caused a longitudinal instability was raised an average of 0.13 in the range of Mach numbers from 0.90 to 0.94 by an arrangement of vortex generators at 15% chord. The airplane drag coefficient penalty incurred was negligible with the arrangement at 35% of the wing chord, and was 0.0015 at cruising Mach numbers with the arrangement at 15% of the wing chord. The drag due to lift was not appreciably affected by either configuration at Mach numbers of 0.82 and 0.86.

Results of limited tests up to a Mach number of 0.94 with multiple boundary-layer fences and with the outer two segments of the wing leading-edge slats extended are presented for comparison. From authors' summary

516. Kauffman, W. M., and Drinkwater, F. J., Variable-stability airplanes in lateral-stability research, *Aero. Engng. Rev.* **14,** 8, 29–35, Aug. 1955.

Paper describes briefly a method of varying, in flight, the stability of airplanes, and stresses its research value. Three specific flight applications are discussed: First, surveys leading to flying-qualities appreciation and requirements; second, simulation of proposed aircraft to explore potential handling difficulties; and third, evaluation of promising types of stability augmenters.

Reviewer believes method gives researcher a valuable tool; he would like more specific information on flying qualities acceptable to pilots. J. M. Evans, Australia

517. Costilow, E. L., and Huppert, M. C., Rotating-stall characteristics of a rotor with high hub-tip radius ratio, *NACA TN* 3518, 59 pp., Aug. 1955.

A single-stage axial flow compressor with a 0.9 hub-tip ratio rotor was used in this investigation by the authors who summarize their findings as follows:

"Stall patterns consisting of two, three, and one total-span stall zones developed in that order upon reduction of flow coefficient. The one-stall-zone pattern caused the most severe pressure, temperature, and flow fluctuations. As the flow decreased within the stall zone, detailed measurements showed an increase in static pressure within the stall zone upstream of the rotor and a static-pressure decrease downstream of the rotor. These pressure fluctuations were of sufficient amplitude in the case of the one-stall-zone pattern to result in a pressure drop across the rotor

within the stall zone. All stall zones rotated in the direction of rotor rotation relative to the compressor casing and at a speed proportional to but less than rotor speed. The measured stall-propagation rates were compared with those predicted by theory. The relative stall-propagation rate increased with increasing stall-zone size."

In the appendix of the report are numerous graphs and photographs showing the pattern and frequency of the various stalls. These indicate the effect of rotating stall on compressor performance, and reviewer believes this type of data can be used in avoiding compressor-blade vibration and fatigue.

From authors' summary by A. S. Andes, USA

518. **Tapscott, R. J., and Gessow, A., Supplementary charts for estimating performance of high-performance helicopters,** *NACA TN* 3482, 31 pp., July 1955.

Charts published in *NACA TN* 3323 [AMR 8, Rev. 2474], for estimating the performance of high-performance helicopters, were applicable to rotors having hinged rectangular blades with a linear twist of −80°. Supplementary charts are presented herein covering twists of 0° and −16°. From authors' summary

519. **Stafford, R. S., Some aerodynamic and aeroelastic characteristics of the crescent wing,** *Ingenieur* **67,** 25, 33–37, June 1955.

The advantages of the crescent wing above the sweptback wing for aircraft crusing at high altitude and high Mach numbers are mentioned. The performance and weight aspects of the crescent wing are discussed in comparison with other layouts.

From author's summary

520. **Nelson, W. H., and Krumm, W. J., The transonic characteristics of 38 cambered rectangular wings of varying aspect ratio and thickness as determined by the transonic-bump technique,** *NACA TN* 3502, 173 pp., June 1955.

An investigation to determine the effects of camber on the aerodynamic characteristics of a series of rectangular wings having various aspect ratios and thickness-to-chord ratios was conducted in the Ames 16-ft high-speed wind tunnel, utilizing the transonic-bump method. The Mach number range of the investigation was from 0.6 to 1.12, with a corresponding Reynolds number range of 1.7 to 2.2 million. The lift, drag, and pitching-moment data are presented for wings having aspect ratios of 4, 3, 2, 1.5, and 1, and NACA 63A2XX and 63A4XX sections with thickness-to-chord ratios of 10, 8, 6, 4, and 2%.

From authors' summary

521. **Chapman, D. R., and Kester, R. H., Effect of trailing-edge thickness on lift at supersonic velocities,** *NACA TN* 3504, 20 pp., June 1955.

Measurements of lift were made on various rectangular-planform wings differing in trailing-edge thickness, profile shape, maximum thickness ratio, and aspect ratio. The experiments were conducted at Mach numbers between 1.5 and 3.1, at Reynolds numbers between 0.55 and 2.2 million, and on wings with and without boundary-layer trips. The measurements are compared to theoretical calculations based on both second-order and shock-expansion theory. Calculated results using shock-expansion theory are presented for Mach numbers between 1.5 and 10.

In all cases the experimental values of lift-curve slope for wings having a blunt trailing edge were higher than those for wings of equal thickness ratio having a sharp trailing edge, with the difference in most cases varying from a few per cent to about 15 per cent, depending primarily on trailing-edge thickness. The agreement between theoretical calculations and experiment was reasonably good. The calculations for 5%-thick airfoils at 5° angle of attack in the Mach number range between 7 and infinity indicate between about 15 and 25% higher lift for full-blunt airfoils than for sharp-trailing-edge airfoils.

From authors' summary

522. **Daley, B. N., and Lord, D. R., Aerodynamic characteristics of several 6-percent-thick airfoils at angles of attack from 0° to 20° at high subsonic speeds,** *NACA TN* 3424, 57 pp., May 1955.

Aerodynamic characteristics obtained from two-dimensional tests of eight 6% thick symmetrical airfoils of the supersonic and subsonic type are presented at angles of attack from 0° to 20° and at Mach numbers from 0.3 to about 0.9. Results indicate generally improved characteristics for the circular-arc and wedge-type airfoils when the maximum thickness was located forward. The variations with Mach number of the lift, drag, and pitching-moment coefficients are generally similar for those supersonic- and subsonic-type airfoils tested.

From authors' summary

523. **Tosti, L. P., and Davenport, E. E., Hovering flight tests of a four-engine-transport vertical take-off airplane model utilizing a large flap and extensible vanes for redirecting the propeller slipstream,** *NACA TN* 3440, 26 pp., May 1955.

An investigation of the take-off, landing, and hovering flight characteristics of a four-engine-transport, vertical take-off airplane has been conducted with a remotely controlled free-flight model. The model had four propellers distributed along the wing with thrust axes parallel to the fuselage axis. In order to produce direct lift for hovering flight, the propeller slipstream was deflected downward about 70° by a full-span 65% chord flap deflected 90° and eight extensible vanes arranged above the wing in a cascade relation. From authors' summary

524. **Seaberg, E. C., Theoretical investigation of a proportional-plus-flicker automatic pilot,** *NACA TN* 3427, 53 pp., May 1955.

Analysis of stability of supersonic canard airframe and proportional-plus-flicker autopilot. Autopilot maintains zero reference about which output is proportional to input; flicker response overrides proportional response at fixed angle of gimbal displacement on either side of reference. Calculated transient responses are investigated for variation of autopilot and aerodynamic parameters. (From author's summary)

Reviewer believes the contribution is original and of practical interest. Technique for investigating absolute stability is poor since a more effective tool is available via the describing function (harmonic balance) technique.

Bibliography is inadequate since no source is given for previous work on flicker servos, but unnecessary reference is made for techniques that are familiar and well worn.

L. A. Gould, USA

525. **Müller, W., The effect of an enlarged head on the inertia coefficients and yawing moment of a body moving in a fluid** (in German), *Öst. Ing.-Arch.* **9,** 1, 1–11, 1955.

Source-sink methods are used to solve the axial flow (exactly) and cross flow (approximately) past a certain axisymmetric body having a large spherical head and a prolate spheroidal body. The inertia coefficients and yawing moment, found by established methods, are intermediate between those of a sphere and of a spheroid with the same length and volume as the chosen body.

The paper is an interesting exercise in ellipsoidal coordinates, but reviewer feels that the conclusions would be considerably modified by flow separation in a real fluid.

A H. Armstrong, England

526. Nickel, K., The maximum lift of airfoils (in German), *ZAMM* **34,** 10/11, 374–385, Oct./Nov. 1954.

The maximum lift under a restraining condition (either rolling moment or pitching moment predetermined) is investigated mathematically, disregarding the mutual induction between wing cross sections. The optimum condition is fulfilled if the local lift coefficient is equal to the maximum coefficient up to a certain point of the wing span, where it changes discontinuously into the minimum lift coefficient. The point of change is calculated and the lift loss due to restraining conditions is plotted for two families of examples containing the wing-taper ratio as parameter. G. W. Braun, USA

527. Wallis, R. A., Experiments with air jets to control the nose stall on a 3 ft chord NACA 64A006 aerofoil, *Aero. Res. consult. Comm. aero. Res. Lab. Melbourne, Austral., Note* 139, 29 pp. and 21 figs., Sept. 1954.

Experiments on an NACA 64A006 two-dimensional airfoil have shown that air jets on the lower surface of the nose can be used to suppress the laminar separation "bubble," thereby improving the stalling characteristics of the air foil. In one series of tests, additional air jets on the upper surface near the leading edge effected an appreciable delay in turbulent separation from the nose.

Air jets increased the "nose-stall" lift by 58% to 65% and 22% to 28% for the unflapped and flapped airfoil, respectively, at a Reynolds number of 1.9×10^6. Maximum lift was increased by 10% on the unflapped airfoil, but with the flap there was no change. At the higher incidences, drag was greatly reduced. Some delay in the large nose-down pitching-moment change with incidence was achieved. From author's summary

528. Hyatt, A., A method for estimating wing weights, *J. aero. Sci.* **21,** 6, 363–372, June 1954.

An equation for estimating wing weights is developed which gives reasonably accurate results when compared with actual military and commercial aircraft. The variables included in the equation consist of the wing geometry dimensions, basic flight design weight, ultimate load factor, maximum equivalent sea-level speed, and an equivalent stress factor. A wing weight can be computed in approximately 30 min. The weight includes flaps and ailerons as well as leading-edge slats or flaps in the case of swept wings. The effects of distributed wing weight and concentrated weight items in the wing are taken into account.

From author's summary by H. Mirels, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 519, 541)

529. Fung, Y. C., An introduction to the theory of aeroelasticity, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, ix + 490 pp. $10.50.

The necessity for extensive aeroelastic investigations has been generally accepted in the design of present-day aircraft. However, practically all the fundamental and advanced knowledge of this field is contained in the form of technical papers devoted to specific problems. Thus there exists a great need to consolidate these works and present them in an organized manner.

Author correctly states: "As this book is not intended to be a compendium or a handbook, attention is directed only to the fundamental principles." The first chapter presents some basic information on elasticity, aerodynamics, and mechanical vibrations. Later chapters deal with (2) some aeroelastic problems in civil and mechanical engineering, (3) divergence of a lifting surface, (4) steady-state aeroelastic problems in general, (5) flutter phenomenon, (6) fundamentals of flutter analysis, (7) engineering flutter analysis and structural design, (8) transient loads, gusts, (9) buffeting and stall flutter, (10) applications of Laplace transformation, (11) general formulation of aeroelastic problems, (12) fundamentals of nonstationary airfoil theory, (13) oscillating airfoils in two-dimensional incompressible flow, (14) oscillating airfoils in two-dimensional compressible flow, and (15) unsteady motions in general experiments.

The book thus fulfills, to a large degree, the need for a consolidated treatment of the fundamentals of aeroelasticity. However, a lack of sufficient illustrative calculations, problems, and experimental data reduces the effectiveness of the book. This is based on the reviewer's experience that a better understanding of the subject matter results if the afore-mentioned are included. An extensive bibliography is presented at the end of each chapter and is indexed so as to be extremely useful as a guide to further study. L. Goland, USA

530. Gruschwitz, E., Computation and discussion of flutter safety of aircraft (in German), *ZAMP* **6,** 4, 296–315, July 1955.

A set of three integral equations for the components of the relative displacement vector are used to describe the flutter oscillations of an aircraft. Two methods for the approximate solution are presented, one making use of the eigenvector functions and eigenvalues of the problem without air forces, the other being Rauscher's method of station functions in a slightly generalized form. Then numerical methods for finding the zeros of the flutter determinants are given. The paper concludes with a short description of actual numerical computations on automatic computing machines. From author's summary

531. Niedenfuhr, F. W., On the possibility of aeroelastic reversal of propeller blades, *J. aero. Sci.* **22,** 6, 438–440 (Readers' Forum), June 1955.

The purpose of this note is to call attention to an elastic instability effect that may occur on thin pretwisted propeller blades or other similar sections. From author's summary

532. Kennedy, E. C., Methods for computing supersonic aerodynamic flutter coefficients for two-dimensional flow, *J. aero. Sci.* **22,** 5, 310–312, May 1955.

In the theory of unsteady supersonic aerodynamics, certain finite integrals containing trigonometric and Bessel functions have to be evaluated. In this paper, a method is described for calculating these integrals by series development of the Bessel functions and integration termwise. All integrals can be calculated directly without using available recurrence formulas.

Reviewer wants to draw attention to a paper of L. Schwarz [*Luftfahrtforschung* **20,** 12, 341–372, 1943], where the zero-order integrals as the fundamental integrals in the recurrence formulas are tabulated for a wide range of Mach number and reduced frequency. H. Merbt, Sweden

533. Söhngen, H., Aerodynamic forces on a vibrating cascade of blades (in German), *ZAMM* **35,** 3, 81–88, Mar. 1955.

A mathematical expression is derived for the lift distribution of an unstaggered cascade of blades which are oscillating in phase with each other in a stream parallel to the blades.

The derivation is based on the assumption that the vertical component of the velocity at any blade station is induced by both the bound vortexes of each blade and the free vortexes which are shed (proportionally to the time rate of change of the circulation about the blades). If the ratio of the distance between two consecutive blades and the chord length of a blade is equal to or less than 0.5, assumptions can be introduced which simplify the final expressions with only small loss in accuracy.

L. Goland, USA

534. **Boit, M. A., The divergence of supersonic wings including chordwise bending,** *Cornell aero. Lab. Rep.* no. 67, 56 pp., Dec. 1954.

The static aeroelastic stability or divergence problem is investigated for supersonic wings considering spanwise bending and twist as well as chordwise bending. The problem is investigated by looking at the parameters affecting chordwise divergence by successively introducing different effects on simple models. In all, seven steps are taken. Section 1 deals with chordwise divergence of a two-dimensional wedge-shaped airfoil, section 3 deals with chordwise divergence of a biconvex profile, while succeeding sections deal with introducing the effects of spanwise bending and torsion. It is found that the effect of Poisson's ratio on anticlastic curvature has a large effect for small wing deformations. It is found that a generalized coordinate approach can give good answers and, hence, provides a means for introducing aspect-ratio effects on the airload distribution. Wing thickness effects were also studied.

This paper gives a good insight into the problems associated with chordwise divergence and should provide a starting place for studies on chordwise divergence of complicated wing structures.

J. E. Stevens, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 378, 531, 544, 545, 546, 547, 555, 559, 581, 598, 599, 600)

535. **Kendall, J., Generation of high gas pressure through hydraulics,** *Jet Propulsion* **25,** 9, part 1, 446–448, 467, Sept. 1955.

Paper covers the development of a type of portable ground-handling equipment capable of furnishing high-pressure gas in ranges up to 6000 psi, and describes the means by which this high-pressure gas is developed through the utilization of high-pressure variable volume hydraulic pumps and Greer high-pressure transfer barriers connected to plenum chambers to store the high-pressure gas until required. The transfer barrier acts as a means of separating the high-pressure oil (which is used to develop the high-gas pressure) from the actual gas itself in order that, in the development of this pressure, the gas is not contaminated in any way by oil or moisture of any type. By a predetermined cycling arrangement the desired volume and rate of gas desired can be controlled to satisfy the operator's requirements, based upon selection of the capacity of the pump and the number of transfer barriers employed. From author's summary

536. **Kemp, N. H., and Sears, W. R., The unsteady forces due to viscous wakes in turbomachines,** *J. aero. Sci.* **22,** 7, 478–483, July 1955.

The configuration of viscous wakes of cascade blades is approximated from single airfoil experiments. The unsteady force and moment on a downstream blade passing through such wakes is then calculated on the basis of the theory of isolated thin airfoils in nonuniform motion. The results indicate that the force is nearly proportional to the profile-drag coefficient of the upstream blades. For typical values of this coefficient and conventional cascade geometry the unsteady forces arising from passage through viscous wakes are of about the same size as those due to aerodynamic interference between the moving blade rows, previously estimated [AMR **7,** Rev. 1919].

From authors' summary by P. Schwaar, France

537. **MacGregor, C. A., A note on simplified single spool turbojet equilibrium operation,** *J. aero. Sci.* **22,** 6, 431–432 (Readers' Forum), June 1955.

The analysis of the equilibrium operation of a single spool turbojet engine having fixed geometry may be simplified by considering that the turbine nozzle and some fixed area at the turbine exit are both choked. For most conditions, this assumption is valid because of the large pressure ratio across the jet nozzle. This assumption reduces the turbine operation to a point on its performance map.

For a given compressor inlet temperature and pressure (flight Mach number and altitude) and a constant jet nozzle area, the thrust will be a maximum for constant mechanical rpm and combustion temperature operation. In general, this type of operation is not possible for this case, because there is only one independent variable. However, there is one compressor corrected air-flow-rpm characteristic with which this type of operation is possible. This note determines what the compressor corrected air-flow-rpm characteristics must be to permit this constant rpm, constant combustion temperature, and constant jet nozzle area operation.

From author's summary

538. **Helmbold, H. B., Comparison of mixing processes in subsonic jet pumps,** *J. aero. Sci.* **22,** 6, 435–437, June 1955.

Note in Readers' Forum.

539. **Prian, V. D., Kramer, J. J., and Wu, C.-H., Theoretical analysis of incompressible flow through a radial-inlet centrifugal impeller at various weight flows. I. Solution by a matrix method and comparison with an approximate method,** *NACA TN* 3448, 39 pp., June 1955.

Using the differential equations established in a generalized theory of turbomachines [*NACA TN* 2604], authors formulate and solve numerically the Dirichlet problem that covers the flow through radial and mixed flow impellers constrained to a mean stream surface of revolution with variable thickness. The linearity of the problem introduced by neglecting compressibility permits the superposition of simple flows to obtain the solution.

Numerical calculation presents the incidence, slip factor, velocity distributions of an existing impeller. No attempt is made to compare with experimental data; however, comparison of the velocity distributions is made with that given by the "channel theory," an approximate method [*NACA TN* 2421]. As expected, differences appear at the leading and trailing edge regions of the blade passage. Theoretical results indicate further that the incidence of the inducer can be predicted correctly when the clogging effect of the blade is used with the annulus area.

N. Van Le, USA

540. **Kramer, J. J., Theoretical analysis of incompressible flow through a radial-inlet centrifugal impeller at various weight flows. II. Solution in leading-edge region by relaxation methods,** *NACA TN* 3449, 19 pp., June 1955.

From the results of part I, author refines the numerical calculation to obtain the velocity distribution on the leading edge of the inducer. No study is made for the effect of a variation in boundary conditions on the rapidly changing flow field around the stagnation point. Best impeller performance is reported at a slightly positive incidence of the inducer where calculated velocity gradient is far from minimum. (See preceding review.)

N. Van Le, USA

541. **Meller, A. G., Schematic studies of unsteady aerodynamic forces** (in French), *Rech. aéro.* no. 44, 23–27, Mar./Apr. 1955.

The unsteady part of the lift on rotor blades in the wakes of stator blades is calculated, assuming (1) two-dimensional incompressible flow; (2) only direction of relative velocity w is time dependent; (3) the blades are flat plates following the law $\Delta c_l/\Delta\alpha = K(t)$, where c_l is lift coefficient, $K(t)$ Küssner transfer function

[*Luftfahrtforschung*, Dec. 20, 1936], which indicates the time delay of lift when α is changed by a step.

By Green's method, a closed general integral expression is found for the unsteady lift which is integrated for $K(t) = 1.37 [1 - 0.48 \exp(-2.48t) - 0.52 \exp(-1.83t)]$ where $t = 2wT/c$ (T time, c rotor blade chord), and the particular case of a square wake. A numerical example with data from a tested machine leads to a 30% lift variation. This agrees with extrapolated curves of Sears [AMR **7**, Rev. 1919].

Reviewer finds that agreement is apparent only, since result of Sears includes physical effects of equal magnitude other than the wakes. H. P. Eichenberger, USA

542. Payne, P. R., Power loss and fuel pressure rise due to centrifugal pumping in tip-driven helicopter rotors, *J. roy. aero. Soc.* **59,** 533, 360–362, May 1955.

Flow and Flight Test Techniques

(See also Revs. 449, 527, 597)

543. Allen, W. A., Mapes, J. M., and Mayfield, E. B., Shock waves in air produced by waves in a plate, *J. appl. Phys.* **26,** 9, 1173–1175, Sept. 1955.

A shadowgraphic technique has been used to measure surface motion of a series of steel plates while they deform under impact caused by $^1/_2$-in. diam steel cylinders fired into their back surfaces at about 2800 ft/sec. The strength of the air shock produced when an initial longitudinal wave in a plate strikes the free surface of the plate has been inferred from the measured shock-wave velocity in the air. The shock strength has been related to particle velocity of the surface of the plate. The results are compared to previous work involving contact explosions of small charges on plates. From authors' summary

544. Allen, H. W., and Kofskey, M. G., Visualization study of secondary flows in turbine rotor tip regions, *NACA TN* 3519, 33 pp., Sept. 1955.

Smoke was used to visualize the secondary-flow phenomena in the rotor-blade tip region of a low-speed turbine, and measurements of the factors affecting the flow patterns were recorded from visual observations.

Cross-channel flow and passage vortex formation observed in rotor-blade passages were similar to those found in stationary shrouded blade rows. However, because of the clearance space and relative motion between blade tip and shroud, additional flows and modifications of cross-channel flow resulted. The clearance space gave rise to a tip-leakage vortex at low rotor speeds; and, when the relative motion between blade tip and shroud was of sufficient magnitude, a scraping vortex was produced.

A region of rotor speeds with no definite vortex pattern existed between the tip-leakage vortex region and the scraping vortex region. This region of transition appeared to represent a condition of reduced disturbance in main flow at the rotor-blade tip. At large clearances where the mainstream air governed the flow pattern, the rotor speed required to reach transition was a function of axial airspeed and did not depend on clearance. For smaller clearances where the rotor-blade tip was in the shroud boundary layer, transition depended on clearance and boundary-layer velocity profile. Results of large changes in blade camber showed no observable effect on transition rotor tip speed. Increases in angle of incidence from zero resulted in increased transition rotor tip speed due to increases in the component of air flow normal to the mean camber line at the point of smoke introduction and observation. Installation of a flow fence on the rotor-blade tip as a means of reducing tip-clearance flow across the blade tip from pressure to suction surface resulted in a reduction of transition rotor speed.

Preliminary comparison of results at low speed with actual turbine operating data indicates that turbines normally operate in a region where scraping effect would be expected. Although the results obtained from this investigation are not intended to be applied directly to blade design at higher airspeeds, they should serve as a guide in extending the investigation to higher values of airspeeds and tip speeds which are encountered in actual turbine operation. From authors' summary

545. Bowman, J. S., Jr., Free-spinning-tunnel investigation of gyroscopic effects of jet-engine rotating parts (or of rotating propellers) on spin and spin recovery, *NACA TN* 3480, 21 pp., Aug. 1955.

An investigation has been initiated in the Langley 20-ft free-spinning tunnel to study the gyroscopic effects of jet-engine rotating parts (or of rotating propellers) on the erect spin and spin-recovery characteristics. A $^1/_{21}$-scale model of a military attack airplane was arbitrarily used, and tests were made at a basic loading (mass distributed chiefly along the fuselage) and at alternate loadings (additional mass distributed along the wings).

The angular momentum of the rotating parts was simulated on the model by a rotating flywheel powered by a model airplane engine. The rotating flywheel (clockwise as viewed from cockpit) generally caused the model to spin at a decreased angle of attack and an increased rate of rotation in right spins, and at an increased angle of attack and a decreased rate of rotation in left spins. For the basic loading, rotating the flywheel generally changed the recovery characteristics from satisfactory to unsatisfactory for right spins, but for left spins the satisfactory recovery characteristics obtainable with the flywheel not rotating were not appreciably altered. For the alternate loadings, rotating the flywheel had, in general, little discernible net effect on recovery characteristics. From author's summary

546. Maglieri, D. J., and Reisert, T. D., Gust-tunnel investigation of the effect of a sharp-edge gust on the flapwise blade bending moments of a model helicopter rotor, *NACA TN* 3470, 24 pp., Aug. 1955.

By mounting a model helicopter rotor on the end of a whirling arm which passed through a vertical gust-simulating, low-speed wind tunnel and by measuring the induced vibratory bending stresses on the blades, the influence of gusts on flapwise bending moments was studied. Tests were made for two conditions of blade root fixation (fixed and teetering) and for a range of tip-speed ratios. Results indicate that maximum vibratory bending moments are of less importance for teetering rotor than for fixed rotor and give variation of gust effect with various parameters.
P. A. Libby, USA

547. Eschler, H., Turbine testing in the Simbach-Braunau power plant on Inn River (in German), *Schweiz. Bauztg.*, **73,** 31, 471–474, July 1955.

Article is of interest because a new type of instrument was successfully applied under conditions habitually abnormal. Current-meter measurements were performed in the inlet to a spiral case of a 24,000-kw Kaplan turbine; streamlines are inclined here at 78 to 68° to vertical gate slot. 24 Ott meters were fixed on two frames for vertical shifting. A new, so-called component runner was applied to measure directly a normal projection of oblique velocities. Such a runner gives correct projections automatically up to 45° of deviation from normal. 104 points were taken in every three sections of inlet; results of observations were elaborated by graphical integration. Probable

error in discharge is estimated as ±1.5%. Efficiency of turbines obtained were 1.5 to 2.8% higher than guaranteed by the manufacturer. S. Kolupaila, USA

548. **Howes, W. L., and Buchele, D. R., Practical considerations in specific applications of gas-flow interferometry,** *NACA TN* 3507, 95 pp., July 1955.

This is an extension of a previous report [AMR **8**, Rev. 3168] in which are derived the interferometric equations for one-dimensional density fields. Besides considering the well-known optical refraction effects, authors obtain corrections to account approximately for the effects on interferograms of boundary layers (a) on wind-tunnel walls and (b) on spanwise ends of models. Various sources of error encountered in fringe-shift measurement are defined and estimated. Several interesting examples of diffraction fringes encountered near the surface of models in one beam of the interferometer are exhibited. The interaction of these fringes with the two beam field of fringes is shown, and criteria for aligning the model with the help of the diffraction fringes discussed.

The improved reduction equations are applied to interferometric data for laminar-boundary-layer density profiles (1) in supersonic flow over an insulated flat plate and (2) in subsonic flow along a thick flat plate with blunt leading edge. As a third example, free convection of air around a heated horizontal cylinder is analyzed interferometrically.

In the first example, the new equations improve the consistency of the data, but leave considerable discrepancy between the theoretical curve and the experimental data. In example (2), consistency of the interferometer measurements with those obtained from probes is very good. Agreement with theory in example (3) seems very satisfactory.

F. D. Bennett, USA

549. **Hill, J. A. F., On the calibration of supersonic wind tunnels,** *J. aero. Sci.* **22**, 6, 441–443, June 1955.

Note in Readers' Forum.

550. **Perls, T. A., and Kissinger, C. W., A barium-titanate accelerometer with wide frequency and acceleration ranges,** *Nat. Bur. Stands. Circ., Rep.* 2390a, 16 pp. and 20 figs., June 1955.

551. **Perls, T. A., and Kissinger, C. W., A large barium-titanate accelerometer for shock-velocity measurements,** *Nat. Bur. Stands. Circ., Rep.* 4121, 9 pp. and 6 figs., June 1955.

Thermodynamics

(See also Revs. 354, 488, 565, 567, 568, 574, 580, 604)

552. **Havemann, H. A., and Narayan Rao, N. N., Studies for a new hot air engine; Part I. A principal thermodynamic analysis. Part II. A further thermodynamic analysis,** *J. Indian Inst. Sci.* **37**, 3, 224–291, July 1955.

Authors investigate the power plant cycle following essentially an exhaust-heated constant-pressure open gas-turbine cycle. In part I, calculated values of thermal efficiency, specific output, and other relevant data are given for the simple cycle with single-stage compression and expansion. In part II, these values are given for the more complicated cycles with multistage compression and expansion.

The treatment is inaccurate and too lengthy. Many symbols and some words are not clearly defined. While the average specific heat of air is said to be calculated to the fifth decimal in the relevant temperature ranges, yet the exponent n (of the actual compression process) is taken as constant and set equal to the actual expansion exponent in the main portion of the work. There is no reason why the theoretical limits of n should be 1 and γ (ratio of specific heats). Actually, for adiabatic but nonisentropic compression, n is greater than γ and the compression work is also greater than the isentropic case. In the analysis of multistage cycles, the heat input for reheating is simply neglected in the denominator of the thermal efficiency.

Most serious defect is the lack of a quantity signifying the effectiveness of heat exchanger. The essential difference of an exhaust-heated cycle from the conventional open cycle with combustion before expansion is that heat addition and regeneration are here combined into one process. Depending upon the effectiveness of the combined heat exchanger, namely upon the temperature of the exhaust gas, the cycle may correspond to one with or without regeneration and the thermal efficiency can vary within wide ranges. The formulas given are those corresponding to a cycle without regeneration.

For the conventional gas-turbine cycle, formulas for efficiency, which with obvious modifications cover all cases investigated, have been given by reviewer [*J. aero. Sci.* **14**, 12, 681–682, Dec. 1947]. L. S. Dzung, Switzerland

553. **Dedebant, G., Carnot's principle with regard to random processes** (in French), *C. R. Acad. Sci. Paris.* **241**, 4, 355–356, July 1955.

A stochastic interpretation of Carnot's principle is given on the assumption of a correlation in the velocity distribution of the molecules of a gas working between two thermostats.

P. Kriezis, Greece

554. **Dauphinee, T. M., An apparatus for comparison of thermocouples,** *Canad. J. Phys.* **33**, 6, 275–285, June 1955.

Paper describes a semiautomatic apparatus for routine or precision comparisons of thermocouples of the same type in the temperature range 0–1100 C. The couples being compared are welded together at the tips and placed in a tube furnace which is heated at rates varying from 10 to 100 C/min. Measurements of carefully annealed thermocouples show that, in the temperature range 300–1100 C platinum–platinum 10% rhodium thermocouple, comparisons may be made to accuracies of ±0.3 μv (±0.03 C) at heating velocities as great as 15 C/min, while accuracies of ±1.5 μv at velocities of 100 C/min are feasible. The furnace temperature is varied by means of a motor-driven variac with automatic reversal at peak temperature. In addition to this standard comparison procedure, provision is made for comparing corresponding elements of the couples, for suppression of all or part of the measured e.m.f., and for measuring the whole e.m.f. of *all* couples when a comparison of different types is desired. The system can be adapted to XY recording with total e.m.f. plotted against e.m.f. differences. From author's summary

555. **Müller, M. A., Can the specific fuel consumption of present day jet engines be decreased,** *Z. Flugwiss.* **3**, 5, 113–118, May 1955.

After an analysis of some gas thermal cycles used in jet-propulsion machines, author emphasizes the advantage of isochoric-isobaric process (Seiliger) with regard to fuel economy. It is reported that a combination of a gas turbine with a special piston engine had been tested with promising results by Heinkel in 1945. Then a gas turbine with a rotating distributor (suggested by Lehnen, 1911) and double circuit (by-pass) is described and its thermal efficiency is calculated. Reviewer remarks that the combination with a piston engine has been successfully realized (Wright, Napier, etc.), while the idea of the revolving transmitter has been, after recent failure, abandoned (BBC, Comprex).

O. Maštovský, Czechoslovakia

556. Wilson, W. A., Design of power-plant tests to insure reliability of results, *Trans. ASME* **77,** 4, 405–408, May 1955.

See AMR **7,** Rev. 1705.

557. Mitra, S. S., On the temperature variation of viscosity of liquids, *J. Indian Chemical Soc.* **32,** 5, 297–301, May 1955.

An equation connecting the viscosity of a liquid with temperature has been derived from the concept of free volume in a liquid. The proportionality of fluidity with free space offers an equation of the type

$$\eta = [A + (B/T) + CT]^3$$

and is fairly applicable to nonassociated pure liquids over wide temperature ranges. For associated liquids, due to the temperature dependence of packing factor and deviations from fluidity-free space proportionality, the equation can be used only within small temperature ranges. From author's summary

558. Shenker, H., Lauritzen, J. I., Jr., Corruccini, R. J., and Lonberger, S. T., Reference tables for thermocouples, *Nat. Bur. Stands. Circ.* 561, iv + 84 pp., Apr. 1955.

Expanded reference tables for platinum vs. platinum-10% rhodium, platinum vs. platinum-13%-rhodium, chromel-alumel, iron-constantan (modified 1913), copper-constantan, and chromel-constantan thermocouples are given with temperature in degrees Celsius (centigrade) and Fahrenheit and electromotive force in millivolts as the arguments. The tables are based upon the absolute electrical units and the International Temperature Scale of 1948. From authors' summary

559. Mludek, H., Nomographic solution methods in steam turbine and generator design (in German), *Maschinenbau-Technik* **4,** 3, 158–164, Mar. 1955.

560. Paoluzi, G., On a new equation of state (in Italian) *Ric. Sci.* **25,** 3, 567–575, Mar. 1955.

Author reviews an equation of state previously found to fit well the critical isotherm by adjustment of three arbitrary parameters. By allowing one of these to vary with temperature, he is now able to fit data at temperatures other than the critical temperature as well. S. Gratch, USA

561. Brauer, P., Temperature measurement with color-sensitive coatings (in German), *ZVDI* **96,** 9, 285–287, Mar. 1954.

Heat and Mass Transfer

(See also Revs. 354, 372, 429, 458, 508, 510, 537, 554, 558, 561, 584, 596)

562. Crandall, S. H., An optimum implicit recurrence formula for the heat conduction equation, *Quart. appl. Math.* **13,** 3, 318–320, Oct. 1955.

Author reviews the convergence and stability characteristics of the general finite-difference approximation for the linear heat-conduction equation. A family of implicit finite-difference approximations is shown to contain a particular formula for which the truncation error is of the order of Δx^6.

P. J. Schneider, USA

563. Weiner, J. H., Transient heat conduction in multiphase media, *Brit. J. appl. Phys.* **6,** 10, 361–363, Oct. 1955.

Author extends Neumann's semi-inverse solution for transient heat conduction in a two-phase semi-infinite material to considerations of a semi-infinite system with an arbitrary number of phase changes. The analysis is applied to a three-phase solidification problem involving two solidification boundaries at uniform liquidus and solidus temperatures. Calculated results are compared with experimental data and a corresponding electrical analog solution.

Reviewer considers this paper an important extension of the analytical methods for handling transient conduction in multiphase media. However, even without consideration of surface resistance and possible nonlinearities associated with nonuniform properties and nonuniform liberation of latent heat, the exact solution cannot be put in closed form. In such a case, an electrical analog appears to be the preferred approach, since it can readily take into account surface resistance and these nonuniformities by use of recently developed nonlinear circuit elements.

P. J. Schneider, USA

564. Harris, W. S., and Hill, L. L., Performance of three types of indirect water heaters, *Univ. Ill. Engng. Exp. Sta. Bull.* 432, 46 pp., Sept. 1955.

565. Lowell, H. H., and Patton, N., Response of homogeneous and two-material laminated cylinders to sinusoidal environmental temperature change, with applications to hot-wire anemometry and thermocouple pyrometry, *NACA TN* 3514, 143 pp., Sept. 1955.

Solutions, by standard methods, and numerical values for equations of plane radial heat flow under conditions are cited. "Effective time-constant" concept for ordinary metallic wires is good enough for engineering calculations. Laminated wires with thin outer shell and relatively low core conductivity will improve frequency response by about an order of magnitude. Valuable features of report are discussion of qualitative effects of parameter values on response, and numerous tables and graphs.

N. Ream, England

566. Bradfield, W. S., and Ballinger, J. G., A comparison of heat transfer characteristics of three aerodynamic shapes for re-entering earth's atmosphere at Mach 12, *J. Brit. interplanetary Soc.* **14,** 4, 185–203, July/Aug. 1955.

Authors apply existing knowledge on high-speed aerodynamics to an interesting aspect of interplanetary missile design. Shapes considered are a flat plate, and two cylindrical bodies—one with a hemispherical nose, and the other with a conical nose; temperatures at comparable points reach maxima of 2600, 3700, and 3500 R, respectively. Paper presents only discussion and graphical results; mathematical developments are outlined briefly. Reviewer feels paper is a satisfactory introduction to one aspect of rocket flight. Many assumptions have been made, but these all seem reasonable for first approximations.

R. R. Hughes, USA

567. Berman, R., Foster, E. L., and Ziman, J. M., Thermal conduction in artificial sapphire crystals at low temperatures. I, Nearly perfect crystals, *Proc. roy. Soc. Lond.* (*A*) **231,** 1184, 130–144, July 1955.

In order to obtain a detailed verification of the theory of thermal conduction in dielectric crystals, measurements have been made on a number of artificial sapphire crystals between 2 and 100 K. In the region of the maximum there are variations in conductivity between crystals from different sources. The highest conductivities measured are about 140 W/cm deg, which suggests that estimates of several hundred watts for the maxima of ideal sapphire crystals are not unreasonable.

At sufficiently low temperatures, the conductivity of a very

perfect, long crystal with *rough* surfaces is observed, in agreement with Casimir's theory of boundary scattering, to be proportional to T^3 and to the radius; the phonon mean free path is then nearly equal to the crystal diameter. *Imperfect* crystals show some anomalous effects. The extension of Casimir's theory to apply to *short* specimens has been verified. Perfect crystals with *smooth* surfaces exhibit some specular reflection of phonons; a statistical description of the surface is proposed which leads to the observed variation of this effect with temperature and is compatible with the results of interferometric examination of the surface.

From authors' summary

568. **Topper, L., Analysis of porous thermal insulating materials,** *Indust. Engng. Chem.* **47**, 7, 1377–1379, July 1955.

The thermal conductivity of a porous solid is computed on the basis of two simple models: one, containing a uniform distribution of the voids as cubes; the other containing the uniform distribution of the voids as spheres. Radiation is included for the cubical model.

More extensive work on thermal flow, spherical and cylindrical models, not including radiation however, has been previously completed by Deissler and Eian ["Investigation of effective thermal conductivities of powders," *NACA RM* E52 C05, 1952].

E. V. Somers, USA

569. **Grosh, R. J., Trabant, E. A., and Hawkins, G. A., Temperature distribution in solids of variable thermal properties heated by moving heat sources,** *Quart. appl. Math.* **13**, 2, 161–167, July 1955.

The heat conduction equation of quasi-stationary state for a moving isotropic solid is nonlinear when the thermal properties are temperature dependent. Authors explain a procedure by which the said equation can be transformed into a linear one. It is applicable only when the variation with temperature of thermal conductivity and that of the product of density and specific heat follow the same law. In other words, the thermal diffusivity of the medium is a constant. Plane, line, and point sources are treated for infinite and finite solids. Aside from the source itself, the other boundary conditions are all of the "no flux" type. Calculated results for temperature distribution during welding of thin stainless steel plates compare favorably with experimental data.

Reviewer noted that the transformation used by the authors is not unlike that suggested by Elrod in his discussion of "Heat transfer through thick insulation on cylindrical enclosures" [*Trans. ASME* **70**, p. 903, 1948].

A few misprints have also been noticed: (1) bottom of p. 163, $\lambda = \frac{1}{2}\alpha$ should be replaced by $\lambda = 1/2\alpha$; (2) Eq. (18) should read $-k_0 f'(T)A(\partial T/\partial x) = q_s$, at $x = 0$; and (3) in Eq. (24), the term $(1 + mT_i^2)$ should read $(1 + mT_i)^2$.

B. T. Chao, USA

570. **Toong, T.-Y., and Kaye, J., Theoretical velocity and temperature profiles for the laminar boundary layer of the flow of a compressible fluid in the entrance region of a tube,** *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., June 1955, 781–785.

Solutions to momentum, continuity, and energy equations have been made with the aid of a differential analyzer for flow of a compressible fluid at a Mach number of 2.8 in the entrance region of a tube. The mathematical analysis is briefly outlined. In the solution it was assumed that the viscosity and thermal conductivity of the fluid were invariant. Properties of air were used in the numerical solution for the two cases: one with and one without transfer of heat to the system. The velocity and temperature profiles in the fluid are assumed to be uniform at the entrance to the tube, where a laminar boundary layer starts to grow. The flow field in the tube is subdivided into a boundary-layer region, increasing in size with distance downstream of the entrance, and a central isentropic core which correspondingly diminishes in size. Properties in the core are considered to be uniform, although varying with distance downstream. With these and other assumptions, the resulting velocity and temperature profiles given compare with those for flow over a flat plate.

D. M. Mason, USA

571. **Ibl, N., New applications of dimensional analysis in problems of mass transfer** (in German), *Chemia* **9**, 6, 135–141, June 1955.

572. **Tifford, A. N., and Chu, S. T., On the flow and temperature fields in a forced flow against a rotating disc,** *Proc. second U.S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., June 1955, 793–800.

Forced flow is directed normal to disk which rotates with constant speed. Incompressible flow and constant fluid properties are assumed. Problem is also significant for flow near stagnation point of rotating bodies of revolution. Earlier solutions of the flow problem were obtained by Schlichting and Truckenbrodt [AMR **6**, Rev. 186] using an approximate method, and by Miss Hannah [*Aero. Res. Counc. Lond. Rep. Mem.* no. 2772, Apr. 1947] by a rigorous method. Solution of the authors is also rigorous, but differs in some details from Hannah's. In this particular case, usual boundary-layer approximations need not be made, but full Navier-Stokes equations can be solved and these yield two ordinary differential equations for the flow field. Solutions for velocity distributions and frictional stress coefficients are given. Agreement with Hannah's results is very good and Schlichting's approximate solution differs by less than 10%. For temperature field, a series development for variable wall temperature is given, but no numerical solutions have been sought.

H. Schuh, Sweden

573. **Crooker, A. M., and Ross, W. L., A note on black body radiation,** *Canad. J. Phys.* **33**, 5, 257–260, May 1955.

Authors present a graphical method for determining both the monochromatic emissive (radiative) power and the quantum flux at different temperatures and for surfaces with different emissivities. The method is based upon some theoretical considerations of Czerny [*Ergeb. exakt. Naturw.* **16**, 70, 1938] which lead to the conclusion that the *shape* of the curve of a logarithmic plot of either monochromatic emissive power or quantum flux against wave length is independent of the temperature; only the numerical scales differ. Accuracy of about 2% is claimed for the graphical procedure.

A. Whillier, South Africa

574. **Hunter, A. T., The monotube once-through boiler for conventional or supercritical pressures,** *Combustion* **25**, 10, 57–61, Apr. 1955.

575. **Jain, S. C., and Krishnan, K. S., The distribution of temperature along a thin rod electrically heated in vacuo. V. Time lag,** *Proc. roy. Soc. Lond.* (*A*) **227**, 1169, 141–154, Jan. 1955.

A theoretical investigation of the growth of temperature due to a small increase in current. In particular it is found that relaxation time is inversely proportional to surface-to-volume ratio and also to the cube of temperature at center. Dependence of lag on filament length is discussed. Comparison is made with experimental data and previous (Straneo) theory.

H. D. Block, USA

576. Nichols, P. L., Jr., and Presson, A. G., Heat conduction in an infinite cylindrical medium with heat generated by a chemical reaction, *J. appl. Phys.* **25,** 12, 1469–1472, Dec. 1954.

Problems on conduction of heat in solids are usually hopelessly difficult when a chemical reaction takes place, for the rate of production of heat by such a reaction is, in general, a complicated function of the temperature (we notice in this regard only the Arrhenius law), and this makes the basic differential equation quite intractable by analytical methods. In the present case (relating to an infinite cylinder with prescribed initial and surface temperatures and with heat generated within it by a chemical reaction), it was not possible to linearize the problem without considerably changing its solution, and so it was decided to solve it for heat-release terms corresponding to zero- and first-order chemical reactions.

To treat the case by means of an electronic differential analyzer, the applicable equations have been expressed, first of all, in dimensionless variable form. Then the solid was assumed to be divided into a central cylindrical core and a number of coaxial layers, and the problem has been reduced to a system of simultaneous difference-differential equations corresponding to separate regions and tractable with the differential analyzer.

Difficult computations have covered a range of activation energies from 10 to 20 kcal/mole and have been utilized to establish empirical formulas for the maximum temperature at the center of the body as a function of the various parameters entering into the problem. The error of the complete solution is probably within 10%.

Reviewer considers the present solution a difficult mathematical work showing clearly the extraordinary difficulty of nonlinear problems in conduction of heat. It is probably quite impossible to treat such questions without the powerful possibilities presented by modern electronic mathematical instruments. The results will doubtless serve as a kind of guide in approaching other difficult problems on conduction of heat.

V. Vodička, Czechoslovakia

577. Goff, J. R., and Harden, J. E., Operating experience with dual circulation boilers using 100 per cent make-up, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-232, 8 pp.

Combustion

(See also Revs. 354, 574, 576, 599, 600)

578. Spalding, D. B., Some fundamentals of combustion (Gas Turbine Series, Vol. II), New York, Academic Press, Inc.; London, Butterworths Scientific Publications, 1955, x + 250 pp. $7.50.

This, the second of a projected 8-volume series on the gas turbine, and a fine work on combustion principles, can serve equally well as a text for newcomers and as a stimulant to old hands in research and design of combustion equipment. Author has assimilated the significant recent research, especially on high intensity combustion, and recasts it as an integrated product of the original work and his own thinking. In many instances Spalding adds his own to existing theories or sketches new ones in corners where they have been lacking.

Discussion of thermodynamics in chap. 1 is a quick coverage of first law, *P-V-T* relationships, and stoichiometry. Chap. 2 on fluid flow is notable for a very complete compressible-flow chart for air. Chap. 3 introduces use of the transfer number, stresses analogies between heat and mass transfer, and paves the way for a more comprehensive chapter on heat and mass transfer with simultaneous chemical reaction. Chap. 5 deals with chemical features of combustion and develops methods of treating interaction of chemical and physical processes to explain, at least semiquantitatively, aspects of ignition, steady flame propagation, and extinction. In this synthesis from recent research, Spalding points up similarities in combustion of solid, liquid, and gaseous fuels that make them susceptible to a rather general treatment. Final chapter, qualitative and rather brief, indicates combustor design principles implied from earlier chapters and suggests lines of research most needed for making combustor design a science.

W. P. Jensen, USA

579. Hill, R. L., Steel-industry uses of viscosity control, *Instrum. and Automat.* **28,** 10, 1732–1734, Oct. 1955.

Fuel oil of uniform blend is required in open-hearth operations if undesirable sulfur is to be eliminated from the end product. Viscosity control of the oil provides a method for obtaining fuel of the quality desired for the burners. Included is a discussion of viscosity, Newtonian and non-Newtonian fluids, and an ultrasonic technique for viscosity control.

From author's summary

580. Slater, F. E., Furnace-atmosphere control by dew-point control, *Instrum. and Automat.* **28,** 10, 1720–1724, Oct. 1955.

Heat treatment of steel requires control of furnace atmosphere. This can be done via control of either CO_2 or dew point (water content). The latter permits closer control of the atmosphere. Techniques for control by dew point include (1) dew-point cup, (2) moisture condensation on cooled mirror or metallic surface, (3) formation of fog on sudden expansion of gas, and (4) conductivity of hygroscopic-salt element. Also mentioned are several nondew-point techniques for atmosphere control.

From author's summary

581. Mueller, K. H., Contribution of chemical reactions to a time lag in nitromethane rocket motors, *Jet Propulsion* **25,** 9, part 1, p. 468, Sept. 1955.

582. Cumming, A. P. C., Nomogram for determination of excess air in combustion, *J. Inst. Fuel* **28,** 342–344, July 1955.

583. Pepperhoff, W., and Grass, G., Influence of the inhomogeneity of the radiation of luminous flames (in German), *Arch. Eisenhüttenw.* **26,** 1, 9–18, Jan. 1955.

Optical methods of flame temperature measurement have been developed primarily for homogeneous gases. An extension of the method is here presented for inhomogeneous flames. Four types of inhomogeneous flame are considered. Flames are divided into two or three finite zones of different temperature and absorptivity. Line-reversal temperature U is found to lie somewhere between the maximum and minimum flame temperature. A temperature, $T(F, S)$, is calculated. Emissive power E in many cases can be calculated from U with sufficient accuracy. For greater accuracy, E is taken as the arithmetic mean of E's calculated from U and $T(F, S)$.

F. O. Woodsome, USA

584. Daws, L. F., and Collins, R. D., Convection and the heating of scrap, *J. Iron Steel Inst. Lond.* **178,** part 4, 349–353, Dec. 1954.

From the suggestion that melting time of charge in open-hearth furnace could be lowered if hot flame gases penetrate to the lower layers of scrap, a theoretical investigation is carried out by treating the charge as a homogeneous porous body of material.

If the Nusselt number is about one, it is found that the time required to heat the charge is reduced by at least 25% for com-

plete gas penetration. Also, if the temperature of the gas is 10% greater than the radiant sources in the furnace, the complete penetration gives a 10% reduction in the heating time.

I. Glassman, USA

Acoustics

(See also Revs. 388, 462, 464, 579)

585. North, W. J., and Coles, W. D., Effect of exhaust-nozzle ejectors on turbojet noise generation, *NACA TN* 3573, 26 pp., Oct. 1955.

Engine noise levels and jet-velocity profiles have been obtained with several turbojet exhaust-nozzle ejectors. An insignificant reduction in total sound power was realized. At subsonic nozzle pressure ratios, total sound power from exhaust-nozzle ejectors or by-pass exit configurations can be calculated from primary-jet parameters only. From authors' summary

586. Anonymous, Automatic analysis of noise and vibration. An integrated range of Danish acoustic equipment, *Auto. Engr.* **45, 10, 411–413, Oct. 1955.**

587. Richardson, E. G., The sounds of impact of a solid on a liquid surface, *Proc. phys. Soc. Lond.* (*B*) **68,** part 8, 428 B, 541–547, Aug. 1955.

The sounds, recorded on a microphone in air and on a hydrophone beneath the liquid, when a solid body strikes the surface are recorded and correlated with cinephotographs of the cavity formed on entry. Measurements of base pressure on a projectile forming a cavity are also made. It appears that the major contribution to the sound comes from pulsations of the cavity.

From author's summary

588. Martin, D. W., Low-frequency tone-radiation demonstrator, *J. acoust. Soc. Amer.* **27,** 4, p. 789, July 1955.

589. Kurbjun, M. C., Noise survey of a 10-foot four-blade turbine-driven propeller under static conditions, *NACA TN* 3422, 25 pp., July 1955.

Over-all sound-level measurements and frequency analyses of tape recordings of the noise emitted from a 10-ft-diam, four-blade propeller mounted on a turbine-powered vehicle have been made under static conditions at stations equally spaced on a 75-ft-radius circle. The over-all propeller-noise pattern was unsymmetrical about the fuselage center line, the maximum sound-pressure level being located in the right rear quadrant. The frequency analysis shows that this unsymmetrical distribution consists primarily of the two lowest propeller harmonics. In the plane of and ahead of the propeller, harmonics as high as the eleventh are important.

Theoretical calculations of the sound-pressure levels by the method of *NACA TN* 2968 predict accurately, for the 10-ft propeller investigated, the location of and the maximum levels to be expected for the over-all noise and the first two propeller harmonics. The calculations do not predict accurately the location of the maximum sound-pressure levels, and the maximum calculated levels are 10 and 13 decibels lower than the maximum measured levels for the third and fourth harmonics, respectively.

The frequency analysis of the recordings obtained at several heights above the ground indicates the presence of a strong reflected wave or waves, other than the ground-reflected wave, that reduced the sound level at the ground as much as 6 decibels. The existence of this phenomenon and the unsymmetrical protuberances about the nose of the airplane which reflect sound waves are possible explanations of the measured unsymmetrical distribution about the airplane center line of the propeller noise.

From author's summary

590. Tyler, J., and Towle, G., A jet exhaust silencer, *Noise Control* **1,** 4, 37–41, 54, July 1955.

A jet-exhaust silencer is described which reduces low-frequency noise and causes the maximum noise to occur at very high audio-frequencies. At these high frequencies, sound is rapidly absorbed in the atmosphere. From authors' summary

591. Robey, D. H., On the radiation impedance of an array of finite cylinders, *J. acoust. Soc. Amer.* **27,** 4, 706–710, July 1955.

A general expression is derived for the radiation impedance of the q^{th} acoustic source in an array of n sources in terms of Green's function for the associated baffle. The theory is applied to a circular cylinder forming the active part of an infinitely long, rigid cylindrical baffle, as well as to an array of such cylinders. If the cylinder radius is much smaller than the wave length, the self-radiation resistance and mutual resistance of the members of such an array can be expressed in terms of sine integrals. Curves are shown for the computed radiation resistance in the case of an array of five cylinders. R. Heller, USA

592. Robey, D. H., On the radiation impedance of the liquid-filled squirting cylinder, *J. acoust. Soc. Amer.* **27,** 4, 711–714, July 1955.

A mathematical determination of the radiation impedance of a hollow, liquid-filled, radially vibrating "squirting" cylinder mounted in the aperture of a rigid wall of thickness equal to the length of the cylinder, the entire arrangement being immersed in a liquid medium of indefinite extent. The liquid within the cylinder need not be the same as the liquid outside. Disregarding viscous and nonlinear effects, results are obtained from which the impedance can be computed at any frequency. In the low-frequency case (cylinder radius much smaller than wave length in contained liquid), the output power is found to fall to zero when length of cylinder equals an integer times wave length of sound in contained liquid. The experimental response of a $BaTiO_3$ "squirter" is shown graphically. R. Heller, USA

593. Raney, W. P., Corelli, J. C., and Westervelt, P. J., Acoustical streaming in the vicinity of a cylinder, *J. acoust. Soc. Amer.* **26,** 6, 1006–1014, Nov. 1954.

Apparently contradictory reports in the literature concerning the acoustic streaming around a right-circular cylinder immersed in a viscous, incompressible fluid can be reconciled by reference to a universal curve giving δ_{DC}/a as a function of a/δ_{AC}, where δ_{DC} is the d-c boundary-layer thickness, δ_{AC} is the a-c boundary-layer thickness, and a is the radius of the cylinder. The existence of such a curve has been verified experimentally for the case of a right-circular cylinder vibrating to and fro in solutions of water and glycerine with kinematic viscosities ranging up to 50 times that of water, over an octave of frequencies. An approximate equation for the form of the universal curve has been obtained theoretically for the case of a thin a-c boundary layer, when the oscillation amplitude is small enough to insure the validity of a first-order perturbation solution.

From authors' summary by G. Moretti, Argentina

594. Miles, J. W., Dispersive reflection at the interface between ideal and viscous media, *J. acoust. Soc. Amer.* **26,** 6, 1015–1018, Nov. 1954.

The effects of viscosity and heat conduction (in the reflecting medium) in producing dispersive reflection of a plane wave at the

plane interface separating two media are investigated. If the reflecting medium is treated as a condensed fluid, heat conduction is found to have no effect, while, in first approximation, viscosity is found to produce no change in amplitude but a phase shift proportional to frequency (and therefore no phase distortion) at angles of incidence above critical and to produce no phase shift but amplitude distortion at angles below critical. This amplitude distortion is found to be important only in the neighborhood of a sharp wave front.

From author's summary by C. Zwikker, Holland

595. Young, J. E., Propagation of sound over single absorptive strips in ducts, *J. acoust. Soc. Amer.* **26,** 5, 804–818, Sept. 1954.

The four walls of a rectangular sound duct are of infinite large impedance except on a finite stretch S_1 of one of the walls. Thus, the normal velocity component vanishes on the walls outside S_1 but is proportionate to pressure (or potential) on S_1. Wave length is large compared with cross-sectional dimensions, so that principal mode predominates outside the region of S_1.

Starting from an interesting integral equation, author derives expressions for transmitted wave downstream and reflected wave upstream, partially using a variational procedure due to Schwinger. However, this last part can claim only limited accuracy since trial functions do not satisfy boundary conditions on S_1.

In order to check theoretical results, transmitted wave intensities are measured for several kinds of absorbing stretches. Agreement is satisfactory in most instances. Formula (70) is incorrect, presumably due to a misprint. G. Plato, Germany

596. Keller, J. B., Decay of spherical sound pulses due to viscosity and heat conduction, *J. acoust. Soc. Amer.* **26,** 1, p. 58, Jan. 1954.

By combining the results of Kirchhoff and Knudsen, the effect of viscosity and heat conduction on a spherical sound pulse is found. A rectangular pulse becomes Gaussian, its peak moves with sound speed, its width increases proportionally to $t^{1/2}$, and its amplitude decreases proportionally to $x^{-3/2}$, where x denotes radial distance from the origin. This behavior is exactly the same as that of a pulse in one dimension, except for an extra factor of $1/x$ which accounts for the spherical spreading.

From author's summary by M. J. P. Musgrave, England

Ballistics, Detonics (Explosions)

(See also Revs. 499, 524, 543)

597. Perls, T. A., and Kissinger, C. W., A jerkmeter for ballistocardiography, *Nat. Bur. Stands. Circ., Rep.* no. 4122, 8 pp. and 9 figs., June 1955.

"Jerk" is defined as the time derivative of acceleration. Simple methods for designing jerkmeters are briefly discussed. The present design consists of a low-frequency (20 cps) piezoelectric accelerometer, the output of which is electrically differentiated. The response of the instrument is flat within $\pm 7\%$ from zero frequency to 18 cps, at 21 C, but changes in response up to 33% are introduced in the range between 10 and 18 cps at temperatures between 12 C and 32 C. A ballistocardiogram is shown, with simultaneous displacement, velocity, acceleration, and jerk records. From authors' summary

598. Samelson, K., Supersonic flow past bodies of revolution at small yaw with attached nose shock (in German), *ZAMM* **35,** 5, 170–175, May 1955.

Author derives the system of characteristic equations and boundary conditions in two independent variables from which the solution for nonslender bodies can be obtained numerically, to the first order in yaw. Results are similar to those of Ferri [AMR **3,** Rev. 1321]. Note that in applications careful attention to the peculiarities of the entropy distribution [see Ferri, AMR **4,** Rev. 1650] is required. R. E. Meyer, Australia

599. Price, E. W., One-dimensional, steady flow with mass addition and the effect of combustion chamber flow on rocket thrust, with a supplement on the integration of the burning equation, *Jet Propulsion* **25,** 2, 61–66, 78, Feb. 1955.

An algebraic solution is presented to the problem of one-dimensional steady-state, adiabatic flow of a perfect gas in a constant area channel with mass addition at constant enthalpy, constant ratio of specific heats and molecular weight, and negligible kinetic energy, using a dimensionless quantity proportional to the mass flux as an independent variable. Properties of the solution are described, and the coupled problems of mass addition mechanism and adjustment of the flow to exterior pressure are discussed for the case of the solid-propellant rocket motor.

From author's summary by S. Edling, Sweden

600. Marble, F. E., Servo-stabilization of low-frequency oscillations in liquid propellant rocket motors, *ZAMP* **6,** 1, 1–34, Jan. 1955.

Extended version of other work by same author [AMR **6,** Rev. 3315] applying Tsien's idea of servo-stabilization to bipropellant motors. Paper contains some printing errors in the equations.

L. Crocco, USA

Soil Mechanics, Seepage

(See also Revs. 442, 535)

601. Wyllie, M. R. J., and Gregory, A. R., Fluid flow through unconsolidated porous aggregates, *Indust. Engng. Chem.* **47,** 7, 1379–1388, July 1955.

Experimental determination of porosities of various aggregates has been made using spheres, cubes, cylinders, and prisms. The results show that the Kozeny-Carman constant is dependent on porosity and particle shape, but the shape factor can be empirically assumed from these data and the surface areas of consolidated porous media can be calculated when the pores are of a reasonably uniform shape and size. The tortuosity seems to be better expressed as $\epsilon^2 F^2$ rather than ϵF, where ϵ = porosity and F = formation resistivity factor; but further theoretical work in this direction is necessary before any positive affirmation is possible regarding the tortuosity. Y. V. G. Acharya, India

602. Biot, M. A., Theory of elasticity and consolidation for a porous anisotropic solid, *J. appl. Phys.* **26,** 2, 182–185, Feb. 1955.

Author's previous theory of elasticity and consolidation for isotropic materials [title source **12,** 155–164, 1941] is extended to the general case of anisotropy. The method of derivation is also different and more direct. The particular cases of transverse isotropy and complete isotropy are discussed.

From author's summary by K. J. Sundquist, Sweden

603. Malíshev, M. V., On the evaluation of the angle of internal friction and cohesion of a loose medium in the limit state of stress (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 7, 122–132, July 1954.

Experimental research was carried out to investigate the influence of all principal stresses on the stability of soils. It proved the necessity of adopting a generalized Huber (-von

Mises) theory of failure, rather than the usually applied one (Mohr-Rankine), which takes into account only the two extreme principal stresses.

The experiments were carried out by means of compression (in the triaxial apparatus) as well as by means of the torsion of specimens of the same sand-soil in a specially devised apparatus, the description of which is given. (The usual shear device would be obviously useless for such investigations because, in this case, the stress distribution is not known.)

From author's summary by D. Radenković, Yugoslavia

Micromeritics

(See also Revs. 382, 568, 589)

604. Thomas, J. W., The diffusion battery method for aerosol particle size determination, *J. Colloid Sci.* **10,** 3, 246–255, June 1955.

The diffusion battery consists of a number of long, narrow, parallel channels through which the fluid moves in streamline flow. Measurement of the fractional penetration of a homogeneous, submicron aerosol through the battery allows the determination of its diffusion constant and particle size. The object of this work was to investigate the validity of the diffusion method.

Circular tube batteries were used to determine diffusion coefficients of gaseous molecules; satisfactory agreement with previous values was obtained. Two parallel plate batteries were used for aerosol particle-size measurement in the 0.15- to 0.40-μ radius range; data were extrapolated to zero flow rate through the battery. Results checked those obtained by the gravity settling method and standard optical methods in the 0.15- to 0.30-μ radius range. Above 0.30-μ radius, the batteries gave low results.

The diffusion battery is applicable for determining particle size from atomic dimensions to radii of about 0.3μ. Battery constructions difficulties, however, essentially limit the method to particles under 0.1-μ radius. From author's summary

605. Mindlin, R. D., Mechanics of granular media, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 13–20.

A mathematical theory of the mechanical behavior of materials composed of discrete elastic grains is developed. The line of attack begins with a consideration of the local forces and deformations at the contact surfaces between adjacent grains. The relations between normal force, contact radius, and displacement are obtained from the Hertz theory of contact of elastic bodies. Corresponding to the Hertz theory, there is a solution of the equations of elasticity which takes into account a tangential force subsequent to the application of a normal force. It is assumed that, in this case, a relative displacement of opposing points on the contact surface takes place and, because of symmetry, it occurs on an annulus. Author presents the different results of this theory: The law of the variation of the inner radius of the annulus of slip as the tangential force is increased; the relative tangential displacement of distant points in the two spheres; the consequences of the reversal of the sense of the tangential force and the energy dissipation caused by oscillations of the tangential force, etc.

A granular body composed of like spheres is now considered; the progress made in the development of the theory is sufficient to enable several interesting predictions, based on it, to be tested experimentally. The theory and the experiments are described in the paper. L. J. Tison, Belgium

Geophysics, Meteorology, Oceanography

606. Tolefson, H. B., Summary of derived gust velocities obtained from measurements within thunderstorms, *NACA TN* 3538, 19 pp., Oct. 1955.

Paper presents the available data on the derived gust velocities in thunderstorms for altitudes up to 34,000 ft. The gust-velocity measurements were obtained from investigations made by the National Advisory Committee for Aeronautics in the vicinity of Langley Field, Va., in 1941 and 1942 and from the operations of the thunderstorm project in 1946 and 1947. The derived gust velocities were obtained from the previously evaluated effective gust velocities through use of a conversion factor that is a function of airplane characteristics and altitude. The results indicate that the intensity of the derived gust velocities in thunderstorms is essentially constant for altitudes up to about 20,000 ft, and that an approximate 10% reduction in the intensity occurs as altitude is increased from 20,000 to 30,000 ft. These results apply to the data available for both convective and frontal types of storms.

From author's summary

607. Welander, P., Studies on the general development of motion in a two-dimensional, ideal fluid, *Tellus* **7,** 2, 141–156, May 1955.

Viewed in the small, a flow in which vorticity is conserved cannot reach a final equilibrium state and satisfy the equations of motion. The techniques of statistical mechanics are applied to show that a final equilibrium flow will be reached if the flow field is represented on a large grid so that details are suppressed. Photographs of a square deforming in a fluid are shown. Reviewer feels that this is a definite step toward the understanding of long-term weather changes. J. C. Freeman, USA

608. Hide, R., The character of the equilibrium of an incompressible heavy viscous fluid of variable density: an approximate theory, *Proc. Camb. phil. Soc.* **51,** part 1, 179–201, Jan. 1955.

An analytical study is made of a static fluid to determine the initial behavior of a small disturbance. Three cases are studied. The first case is that of two superposed fluids of great depth, the second is that of two superposed fluids of small depth, and the third is that of a continuously stratified fluid of finite depth. The results of the calculations are illustrated graphically.

R. C. Binder, USA

609. Burns, A., Notes on the dynamic response of an aircraft to gusts and on the variation of gust velocity along the flight path with special reference to measurements made in Lancaster P.D. 119, *Aero. Res. Counc. Rep. Mem.* no. 2759, 18 pp., Sept. 1949, published 1954.

A collection of records showing the time histories of strains and accelerations at various parts of a *Lancaster* flying in turbulent air is presented and discussed. The records include specimens taken in cloud at moderate altitudes and in clear air at low altitudes. Two points of interest regarding the response of the aircraft to gusts are brought to light: (1) The amount of fundamental oscillation excited by a gust appears to be affected to a marked extent by the variation of gust velocity across the span; (2) the amount of oscillation excited does not appear to show any marked decrease as the airspeed of the aircraft is increased. Some decrease in the oscillation excited might be expected due to increase in aerodynamic damping.

An attempt is made to deduce the variation of gust velocity

along the flight path from the measured response of the aircraft. The results indicate that a large up-gust is often closely followed by a large down-gust, and vice versa.

From author's summary

Lubrication; Bearings; Wear

610. Brand, R. S., Inertia forces in lubricating films, *J. appl. Mech.* **22,** 3, 363–364, Sept. 1955.

Theoretical considerations imply that, if an equivalent Reynolds number is of the same order of magnitude as the ratio of bearing radius to mean film thickness, inertia film forces will be of the same order as the viscous film forces. This conclusion is quite significant in high-speed bearings. F. Macks, USA

611. Pinkus, O., Sleeve bearing design: How to select design parameters for optimum combination of load capacity, temperature rise, power loss, lubricant flow, vibration and turbulence, *Prod. Engng.* **26,** 8, 134–139, Aug. 1955.

612. Keller, W. M., Effect of viscosity of car-journal oils on running temperature and other characteristics of journal-bearing performance, *Trans. ASME* **77,** 3, 385–391, Apr. 1955.

See AMR **7,** Rev. 3077.

613. Wilcock, D. F., The hydrodynamic pocket bearing, *Trans. ASME* **77,** 3, 311–319, Apr. 1955.

See AMR **7,** Rev. 1342.

614. Raimondi, A. A., and Boyd, J., The influence of surface profile on the load capacity of thrust bearings with centrally pivoted pads, *Trans. ASME* **77,** 3, 321–330, Apr. 1955.

See AMR **7,** Rev. 3076.

615. Raimondi, A. A., and Boyd, J., Applying bearing theory to the analysis and design of pad-type bearings, *Trans. ASME* **77,** 3, 287–309, Apr. 1955.

See AMR **7,** Rev. 1682.

Marine Engineering Problems

(See also Rev. 434)

616. Rogerson, J., Some observations on marine gearing, *Trans. Inst. mar. Engrs.* **67,** 8, 271–278, Aug. 1955.

Purpose of this paper is to indicate how the loading of marine steam turbine gearing may rise considerably higher than the value calculated on the basis of mean torque. In some instances there are periodic fluctuations of torque having peak values at least 100% in excess of the mean; in other cases the increase is a constant load due to additional resistance to the hull.

From author's summary

617. Takahashi, K., Akita, Y., and Yokoyama, M., Experiment on the strength of the connection of bottom longitudinals and transverse bulkheads in tankers, *Inter. Shipbldg. Progr.* **2,** 12, 384–397, 1955.

A stress study of the connection of bottom longitudinals and transverse bulkheads in a tanker by the use of half-size models has been made under tension. The ordinary type, the thicker type, and the lapped type of brackets were tested in the elastic range and in the partially plastic range. Results suggest that the type which omits the chock nearest to the intersection is better than that with the chock fitted. The thicker bracket has nearly the same performance as the ordinary bracket and the lapped bracket produces a large stress concentration at the lapped end.

From authors' summary

618. Lindgren, H., Critical ship speed, *Inter. Shipbldg. Progr.* **2,** 9, 217–225, 1955.

Author has developed a graphical method for determining the critical speed of ships which is of importance in selecting the economical speed for a given ship hull. Critical speed is defined as speed at which power curve shows a distinct change of slope. Author shows that tangents drawn to high-speed end of resistance curve and low-speed end of resistance curve intersect at point which can be taken as the critical speed.

Analysis of resistance tests of about 300 ship models, most of which were tested at Swedish State Shipbuilding Experimental Tank, by this method indicates important factors affecting critical speed to be block coefficient and position of the longitudinal center of buoyancy. Diagrams of these factors against critical speed for both twin and single screw ships are given. Comparison of data obtained from resistance tests with similar data from propulsion tests shows good agreement. Author concludes with discussion of relation between economical and critical speed.

Reviewer believes paper to be of interest to ship designers and may be useful in selecting ship characteristics for a given speed.

R. B. Couch, USA

619. Van Manen, J. D., and Van Lammeren, W. P. A., The design of wake-adapted screws and their behavior behind the ship, *Inter. Shipbldg. Progr.* **2,** 7, 105–131, 1955.

Method is in close analogy to that in use for a free-running optimum propeller. It requires, therefore, knowledge of both the efficiency and the average factor for the circulation distribution characteristic for a wake-adapted optimum propeller (which could be avoided when developing a method from the known integral equation of the wake-adapted propeller). For the calculation of the product $(c_L l)$, the assumption of the condition of normality is made (which holds for a free-running optimum propeller). Empirical correction is made for the lifting surface effect of the blades. H. W. Lerbs, Germany

620. Grim, O., Calculation of hydrodynamic forces caused by oscillation of ship hulls (in German), *Jahrb. Schiffbautech. Gesellsch.* **47,** 277–299, 1953.

Analysis of vertical and horizontal oscillations of two-dimensional ship hulls. Potential ϕ at water motion composed of that of (1) oscillation in unlimited water, (2) reversed pressure of foregoing at water surface, (3) periodical pressures of $A_n\phi_n$ at water surface within region of ship which, choosing A_n, author adapts to satisfy boundary conditions at ship's surface, exactly in district points of section or with least squares errors. Also a more rough and simple method of approximation is presented.

Considering two-dimensional results applicable at every section of three-dimensional ship, author calculates combined heaving and pitching and—more briefly—combined lateral oscillation and rolling, and compares with experiments. Results are presented in graphs. Good agreement is found—somewhat astonishing with regard to idealized conditions but promising for practical value of method, if confirmed. E. Hogner, Sweden